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4 IC's

17 MIDI

25

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MIDI: EVERYTHING YOU ALWAYS WANTED TO KNOW

BUILD THE ETI LEDSCOPE

COMPLETE 1986 INDEX INSIDE

AUDIO....COMPUTING....MUSIC....RADIO.... ...TICS...

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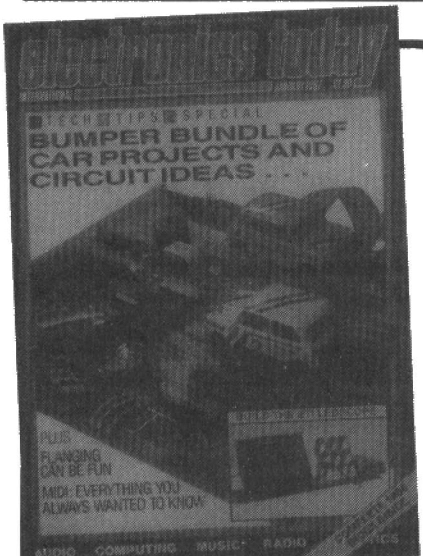
JANUARY 1987 VOL 16 NO 1



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PUBLISHED BY:
Argus Specialist Publications Ltd., 1 Golden Square, London W1R 3AB.
DISTRIBUTED BY:
Argus Press Sales & Distribution Ltd., 12-18 Paul Street, London EC2A 4JS (British Isles)
TYPESET AND ORIGINATION BY:
Design International.
PRINTED BY:
The Garden City Press Ltd.
COVERS DESIGNED BY:
Argus Design.
COVERS PRINTED BY:
Loxley Brothers Ltd.

ISSN 0142-7229

ABC Member of the Audit Bureau of Circulation

■ Subscription Rates. UK: £18.10. Overseas: £22.50. USA: $29.50. Airmail: £49.50.

EDITORIAL AND ADVERTISEMENT OFFICE
1 Golden Square, London W1R 3AB. Telephone 01-437 0626.
Telex 8811896.

FEATURES

PROJECTS

REGULARS

INFORMATION

DIGEST

● Bernard Babani have issued an updated catalogue describing their range of technical books. The titles listed cover a wide range of subjects including audio, computing, construction, faultfinding and servicing, amateur radio, etc, and copies of the catalogue can, be obtained free-of-charge from Bernard Babani (Publishing) Ltd, The Grampians, Shepherds Bush Road, London W6 7NF, tel 01-603 2581.

● *A small error crept into our piece on the Datapen Chiptester in November's News Digest. The telephone number should have been 0256-770 488. Apologies to readers, and also to the owners of the number we published who have been plagued with enquiries they can't answer!*

● Marston-Palmer produce a range of cooling products for use with electronic circuitry, and their latest 12-page brochure describes some of the more specialised items in the range. "Special Cooling Products" covers force-cooling, coldplates, total enclosure cooling and other systems for use where simple heatsinking proves inadequate or undesirable. Copies can be obtained from them at Wobaston Road, Fordhouse, Wolverhampton WV10 6QJ, tel 0902-783361,

● There were less business failures in the electrical engineering industry during the first half of 1986 than there were during the first half of 1985, according to business information company Dun & Bradstreet Ltd. The total dropped from 283 to 264 with the highest number of failures occurring in the South East of the country. In spite of the fall, the failure rate in the electrical engineering industry remains higher than in other sectors of British industry.

● The new, much heralded Maplin catalogue is now available and can be obtained either direct from them or from most High Street newsagents. It describes the usual wide range of components, kits, tools, etc, along with much useful information and many new additions. Maplin are also giving a battery condition tester away free to everyone who purchases the catalogue, plus the chance to win £100.00 credit in a free competition. Maplin Electronic Supplies Ltd, PO Box 3, Rayleigh, Essex SS6 8LR, tel 0702-554 155.

Britain 'Slipping Behind' In Research

Britain invests less money in academic research than its major competitors and is beginning to lose its standing within the international scientific community.

Those are the conclusions of two reports prepared for the Advisory Board to the Research Councils (ABRC), a body set up by the Education Secretary to advise on research and funding.

The problems are said to be particularly acute in the physical sciences, and a list drawn up by worried academics suggests that electronics research is among the areas losing out.

The ABRC report on funding shows that Britain spends less government money on research than any of its principal competitors, the only exception being Japan where far more research funding is available from industry. The Japanese government has also been increasing its investment in research in recent years and may have overtaken Britain since the figures were produced.

The second report examines the international standing of British scientific research and concludes that we are falling behind our competitors, particularly in physics.

The reports are significant because they provide a better base for comparing national levels of research spending than the statistics supplied by the Organisation for Economic Co-operation and Development. The authors, Ben Martin and John Irvine of Sussex University's Science Policy Research Unit, say that it has been all too easy in the past for people to dismiss comparisons of research spending.

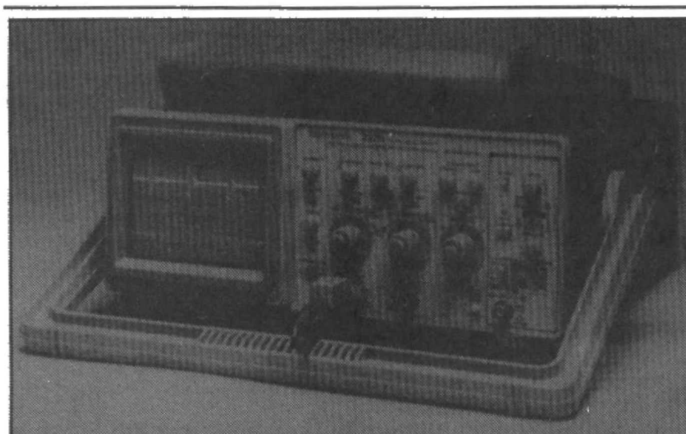
The Chairman of the University Grants Committee, Sir Peter Swinnerton-Dyer, accepts that the figures show Britain to be lagging behind in research investment, but argues that we get better value for money than our rivals. He believes that the situation can be reversed at comparatively little cost and that it would be far cheaper to do so than to let things slide still further.

The reports have been welcomed by the Save British Science Society, a group which claims the support of over 2000 British scientists including more than half of our Nobel laureates. They have compiled a list of 'missed opportunities', instances where the lead in key areas of research has been lost to other countries because of inadequate funding.

One of the examples they quote is that of Professor Connerade of Imperial College, London, whose work was crucial to the development of future generations of sub-micron ICs. The college was unable to obtain a £130,000 grant for the project and the work is now being carried out at a German laboratory. They also claim that Britain's lead in cryogenics and applied superconductivity is being lost through inadequate funding.

The SBSS say that the reports bear out warnings they gave a year ago. They point out that the figures used date from 1982 and claim that the gap has widened since then. In particular, they believe that France and Germany have responded to the challenge of essential research and have found the necessary funds, leaving Britain farther behind than ever.

ABRC Science Policy Studies. No. 1 (Physics) and No. 2 (Funding), 6 Carlton House Terrace, London SW1 5AG. Prices: £14.00 and £12.00 respectively, plus postage and packing.



Low Cost, High Performance Oscilloscopes

Tektronix claim to have broken a price barrier with their dual-channel 2225 portable oscilloscope. At £750.00, it offers 50MHz bandwidth, 500uV sensitivity and a host of other features usually found only on much more expensive instruments.

The 2225 is intended as a general purpose instrument for use in areas such as test, production, education, etc. A selective trigger which can be locked onto either TV line or TV field signals makes it suitable for a wide range of video and television applications, and there is also a filter which can be used to remove high frequency components on low frequency trigger signals and vice versa, making signal stability far easier to achieve in difficult circumstances.

Other features include a peak-to-peak auto-trigger, variable hold-off for triggering on complex waveforms, a beam-locator, and an alternate sweep magnification system. This facility provides many of the benfits of a dual-timebase 'scope, allowing a section of the sweep to be magnified by 5x, 10x or 50x and displayed simultaneously with the main sweep. A 50MHz 10x probe is available for use with the 2225 and features built-in compensation and a highly-durable probe tip.

The 2225 shares the same front panel layout as the other member of the 2200 Series and is said to be very easy to use. Tektronix say that the use of the well-established 2200 Series design base has helped them keep costs down, enabling them to design and manufacture the scope in Britain from British and EEC components yet remain competitive with other products from every part of the world.

The Tektronix 2225 oscilloscope is available now from RS Components and Electroplan as well as from Tektronix themselves. The P6103 probe is also available now and costs £20.

Tektronix UK Ltd, Fourth Avenue, Globe Park, Marlow, Buckinghamshire SL7 1YD, tel 06284 6000.

New Bells Are Ringing

The latest measures in the 'liberalisation' of the British Telecom network came into force at the beginning of December. These measures, proposed by Oftel, the Government's regulatory body for telecoms, remove restrictions on the installation of secondary sockets and extension wiring.

Once the master socket has been installed by BT on any particular premises, further sockets can be added by an independent contractor or even by the telephone users themselves. The hardware concerned will still have to meet with BT approval and carry the green circle symbol if it is to be connected to the BT system, but communications equipment manufacturers are confident that the lifting of restrictions on extensions will boost demand for telephones and related kit.

The managing director of domestic equipment manufacturer Betacom was confident when he spoke recently about his company's future plans. 'With the liberalisation of secondary sockets and extension wiring,' said Dennis Baylin, 'we expect the market to expand rapidly and are therefore striving to develop our major contacts and planning an equally aggressive stance in 1987.'

Neither Oftel nor BT have indicated whether they intend to introduce approval for wiring installations themselves. It is often claimed that the approvals system is designed to avoid potentially hazardous situations, by ensuring that only safe equipment is connected to the telephone system. With customers now able legitimately to connect up their own extension sockets, there is no real safeguard operating at the wiring level.

● While we're on the subject of BT, it may be worth noting that their much-vaunted price cut is something of a con. The reduction of the unit fee from 5p to 4.4p (some 12%) is, in many cases, more than matched by the reduction in time allowed per unit. In the most startling example, the actual cost per second has gone up from 0.055p to 0.073p — a rise of almost 33%. Interestingly, this is for peak-time local calls.

Most long-distance and international calls have actually decreased in cost-per-second, while local calls and calls up to 56km (a-rate) have gone up. The effect will be to favour users of long-distance calls — mostly business — and to hurt the domestic user.

MicroPoetry?

The year's most amusing press release has to be from a US computer software company called MicroProse, suppliers of computer games liek 'F-15 Strike Eagle'. They have just moved UK offices to a 5000 square feet piece of real estate 'overlooking the market square in the picturesque town of Tetbury, Gloucestershire.'

The company's press release gushes, 'this means that among MicroProse Sofware UK's new neighbours will be Prince Charles and Princess Diana, whose home Highgrove is little more than a mile away.' Among their other neighbours will be Mrs. Ethel Splodge of 9, The Villas, Tetbury, but she'll never inspire 'Jet Set Willy HRH', will she?

Amstrad Power

NJC Electronics are marketing an output port for the Amstrad CPC464, 664 and 6128. Based on the ULN2003 darlington driver, the board provides seven outputs capable of sinking up to 500mA at 50V and will allow you to switch relays, small motors and seven segment displays. The board is obtainable from NJC Electronics, 13 Binfield Square, Ella Street, Hull HU5 3AP, and costs £14.95 inclusive.

Time And Again

The Cirkit 2000 is a plug-in timer which allows programmed switching up to six times a day for each day of the week of loads rated at 3kW or less. The LCD display shows time and day of the week as well as the programmed settings. The timer is claimed to be accurate to within two seconds and can be programmed for periods as short as one minute.

Battery back-up is included to avoid loss of program in the event of mains failure or temporary removal and the manual override will bring switching forward without upsetting the program.

The unit costs £32.95 plus VAT and is available from Cirkit Distribution, Park Lane, Broxbourne, Herts EN10 7NQ (0992 444111).

School's Out

It's come to our attention that one of our longest standing advertisers, the British National Radio and Electronics School, has ceased trading.

Unfortunately, we unwittingly carried an advert from this organisation after they ceased trading. Any reader who sent money to the company as a result of this advert may have a claim under the Mail Order Protection Scheme. To clarify their position, they should write with all details to the Advertising Department, ETI, 1 Golden Square, London W1R 3AB.

Readers enrolled on BNR&ES courses are, if possible, being placed on similar courses run by other recognized correspondence shcools. If you receive no notice of a transfer or if you require further details, please telephone the Council for the Accreditation of Correspondence Colleges on 01-935 5391.

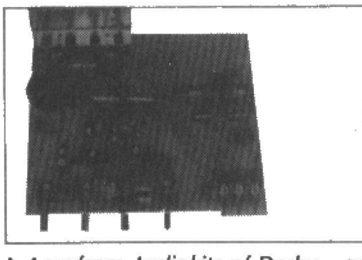
On Air, Off Wire

The first full-scale interactive cable TV system in Europe is to be developed as a joint enterprise between Tandata Holdings of Britain and ITT Nederland in early 1987. The network will operate at first in the South Limburg area of Holland and will offer access to teleshopping and information services by means of a set-top box with integral alphanumeric keypad and infra-red transmitter.

Tandata is already an acknowledged market leader in viewdata and teletext hardware manufacture. In particular, they are well-known for the range of Prestel terminals they provide, advertised in conjunction with the Royal Bank of Scotland's 'home banking service'. Managing director, Roy Pendleton, says that 'development of the set-top box for interactive cable services has provided to be a fascinating task, combining our extensive knowledge of videotex and teletext protocols.'

The South Limburg project will be the first interactive videotex system in Europe not relying on the telephone network. The use of cable can broaden the range of services offered, especially, because there will be no 'time-based communications charges', in the words of Roy Pendleton. Services envisaged include weather and news information, teleshopping, home-banking, burglar and fire alarms and messaging.

Because of the lack of a time-base the system can be left on for extended periods. Despite the apparent advantages of a cable based system, teletext so far has been predominantly an off-shoot of the phone network. This is because of the lack of interactive capacity in existing cable networks and the need to develop a low cost terminal of the sort developed by Tandata. As far as the other consideration goes, this will be taken care of by ITT Nederlands who are operating the order from the Dutch Government to upgrade the existing cable network starting with Limburg.



It's A Mod, Mod Module World

New from Audiokits of Derby comes this complete hi-fi stereo amplifier, less transformer, mounted on a fibreglass PCB. The amp's designer claims that it is capable of providing 30W RMS per channel from a 40V AC supply, although it will work well at supply levels down to 15V AC. The Audiokits Module is designed around a cascode drive stage for better linearity and high frequency response and it boasts two-transistor constant current sources and diode stabilised biasing in the pre-amp — features which Audiokits say are 'normally found only in expensive hi-fi amplifiers.'

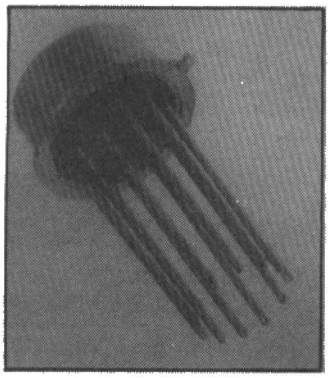
The Module is priced at £37.50 plus £2 p&p, ready built, and is available from Audiokits, 6 Mill Close, Borrowash, Derby DE7 3GU (0332 674929).

●"Noise — the Problem, the Solution" is the title of an 18-page catalogue available from Castle Associates. As well as detailing the range of sound measuring equipment available for sale or hire, the catalogue includes three pages of technical information and definitions. Castle Associates Ltd, Salter Road, Scarborough, YO11 3UZ, tel 0723 585 250.

● Mullard have issued a series of technical notes on their range of varistors, thermistors and sensors. The operation of the devices is explained and the notes also include a guide to the characteristics of various types and hints on selecting a device for a particular application. Mullard Ltd, Mullard House, Torrington Place, London WC1E 7HD, tel 01-580 6633.

● Alpha Electronics have a wide range of test equipment for hire and can also repair and re-calibrate instruments. Their 16-page brochure and price list can be obtained from Unit 5, Linstock Trading Estate, Wigan Road, Atherton M29 0QA, tel 0942-873 434, or from 73, Wester Broom Drive, Corstorphine, Edinburgh EH12 7RR, tel 031-334 5107.

Versatile Mercury Switches



A new range of mercury movement sensors from Saunders-Roe Developments combines small size with an unusually rugged construction, and offers considerable possibilities in movement detection and measurement.

The three switches in the range are all housed in welded steel cases similar in appearance to transistor cans. This construction allows them to be made both smaller and far more rugged than the traditional glass-encapsulated mercury switch.

The switching functions available range from a simple on-off movement sensor through to an omni-directional sensor which has twelve independent contacts. When the switch is moved more than 8° the ball of mercury will form connections between groups of pins, and by digital analysis of the pin conditions it is possible to sense both the magnitude and direction of movement and also to monitor rotational movement.

The switches are manufactured under strictly-controlled conditions in order to reduce the risk of oxygen-related failures. Saunders-Roe claim a life expectancy for the devices well in excess of 250,000 cycles. They can also provide samples of the switches manufacturerd in accordance with defence standard 05-21.

The switches are available from the manufacturers in both large and small quantities at prices from around £1.50 to £4.00. Saunders-Roe Developments Ltd, Hayes, Middlesex, tel 01-573 3800.

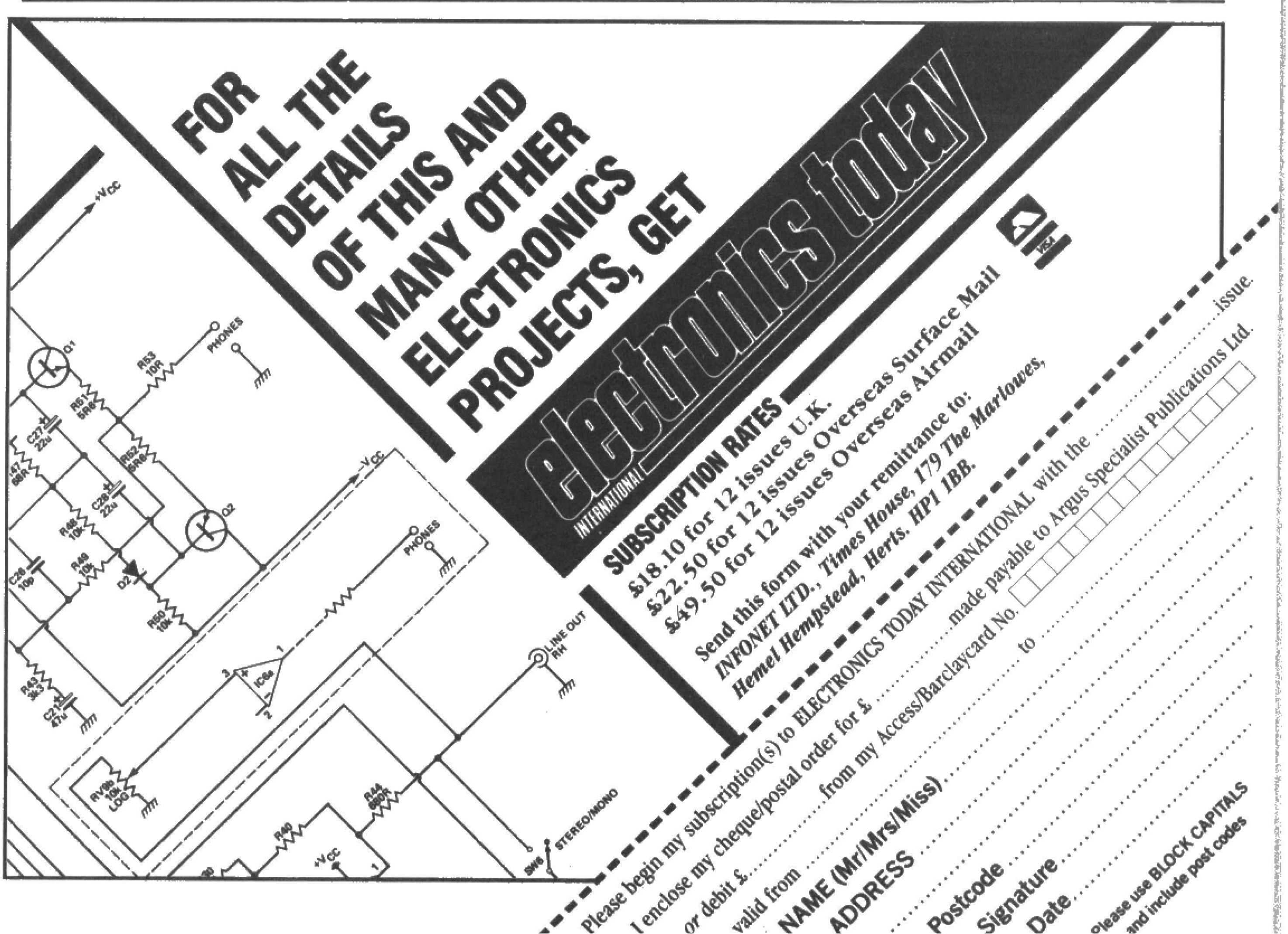
ETI PCB Service

As regular readers will know there have been continuing problems with this service, and we have once again found it necessary to leave the PCB order form out of this issue.

We have now located another supplier who is not only well-equipped technically to handle the service but also has direct experience of the hobbyist market. This was felt to be important in the light of our previous experiences.

Work has already started on clearing the backlog of orders and we hope to be in a position to start handling new orders by next month. In the meantime, we hope you will accept our apologies for the suspension of the service.

● The damaged No.4 reactor at the Chernobyl nuclear power plant has now been completely entombed, along with a number of instruments to enable engineers to monitor the still highly-radioactive core. Meanwhile, the No.1 reactor has been restarted and there are plans to start up reactors no.2 and 3 in the near future. Work is also expected to go-ahead on the half-completed No.5 reactor.



READ/WRITE

Down To Earth Solution

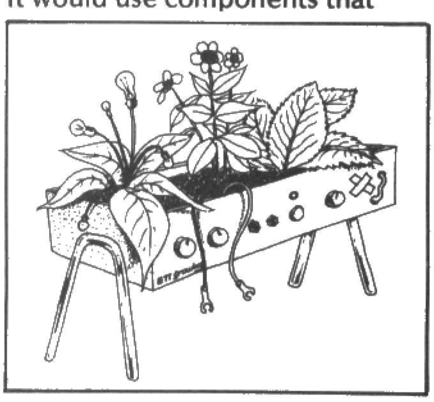
Dear Sir,

Reading a recent letter in ETI regarding the Upgradeable Amplifier (ETI November 1986), it struck me how much heartache something like a kit hi-fi amplifier must cause, especially if it features options, upgrades or is in modular form.

First there is the trauma of deciding whether to go for 'bare bones' or the whole lot, then hand to hand combat with Murphy's law in the construction and use of the item. Inevitably, however, the equipment will eventually become outdated.

Assuming the item is still working, the dread day can be delayed by modifications, upgrades or replacement of strategic modules, inviting yet more wallet-busting and probably guilt in those who have families to support. But then the next great 'breakthrough' comes along and with it a new kit (complete with options, upgrades or modules, no doubt), and the punter is faced with a choice. On the one hand, the new stuff is described in glowing terms, offering improved specifications and a hugely improved performance compared with equipment built only a year or two ago. On the other hand, there is the sentimentality of 'I built it, had it all these years, carried out all the repairs myself' and so on. He or she could always try selling it, but the going rate for kit-built equipment is not terribly high and won't even pay the interest on the loan for the next generation of equipment.

In order to overcome these problems, I would like to suggest a bio-degradeable amplifier project. It would use components that waste away (I know already of capacitors that rot) and perhaps would become quieter with age, fading away until it became a mere whisper or went literally to seed. Just as in life the circuit boards are a riot of colour with their multi-hued components, so in death they could bloom forth in the form of lichen, fern or whatever. The replacement amplifier would be bio-degradeable too, of course . . .



Yours under medication,
Michael Gundy,
Hirwaun,
Mid Glamorgan

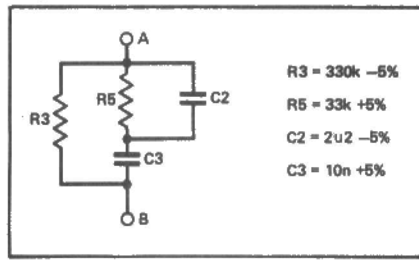
Some Are More Equalised . . .

Dear Sir,

I write concerning Jeff Macaulay's reply to the query raised by a reader, B Wadsworth (ETI November) asking the accuracy of the RIAA replay in his preamplifier. Whereas what is "good enough" may be a matter of opinion, mathematical accuracy is a very different thing.

As I understand the circuit, the gain varies directly according to the net impedance of the four components making up the RIAA network (similar to the valve circuit but with different values). Taking components with 5% variation as shown here, the impedance A to B at 1kHz is 36.7505k ohms. At 150 Hz, the impedance is 99.1148k ohms which is 8.1679 dB above the 1kHz figure. The RIAA requirement is +10.271 dB.

Again, at 30kHz, the impedance is 3.033k ohms or



−21.66 dB as compared with the RIAA figure of −23.12. Neither of these are within the claimed ± 1 dB and this error is widespread.

But of course, the difference is not due principally to the 5% tolerances but to the original values for the components not being in the correct ratios for an accurate response. These are:-

$$R_3/R_5 = 12.38$$

$$R_5C_2 = 81.1us$$

$$R_3C_3 = 2937us$$

Using these ratios and components of 1% tolerance, an accurate RIAA response is assured.

Yours faithfully,
Steve Newing,
Batley,
West Yorkshire

AUNTIE STATIC'S PROBLEM CORNER

Dear Auntie,

Having read the article in ETI November 1986 on bio-feedback, I must say I find it very interesting and will be dabbling with the bio-feedback monitor. I would like to know if you could give me a book list on this subject. Thanking you.

Michael C. Walker,
Woodlesford,
Leeds.

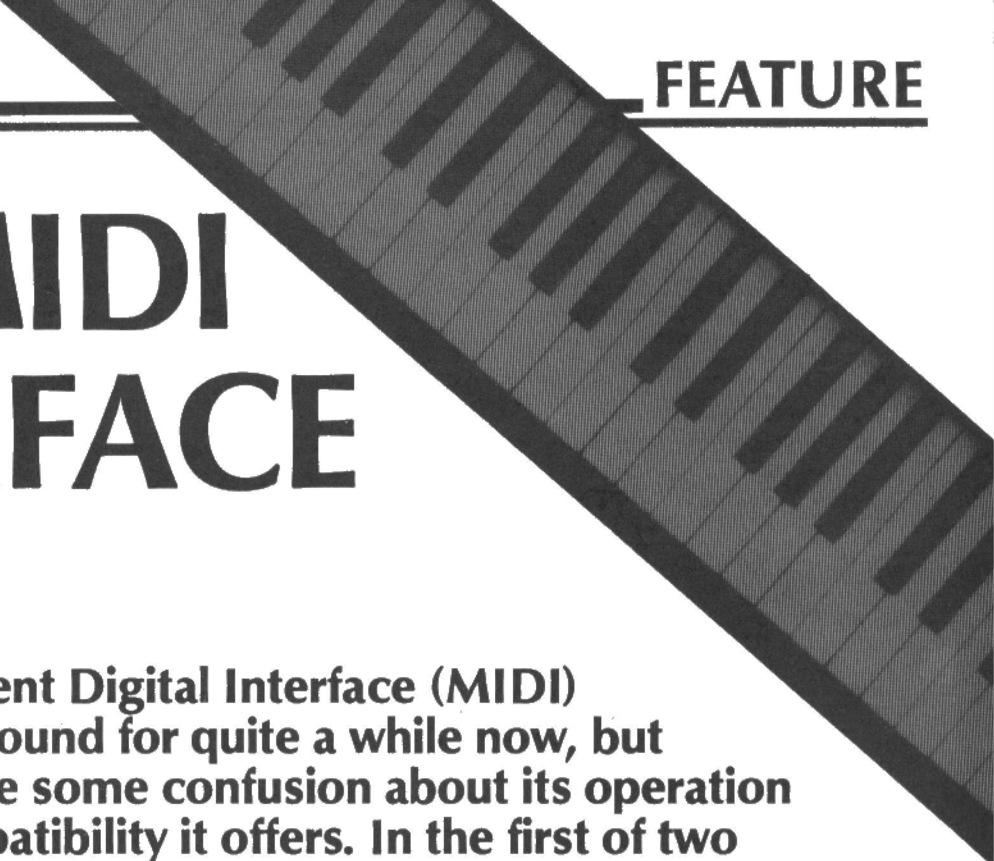
I have received a number of requests for further information on biofeedback, and I hope readers will forgive me if I do not answer them all individually. There are so many books on the subject of bio-feedback that it is hard to know where to begin. A good introduction is: 'Biofeedback And The Control Of Internal Bodily Activity', by R.M. Stern and W.J. Ray.

On the topic of stress and disease, an essential book is Walter Cannon's 'The Wisdom Of The Body', published by W.W. Norton. The book was written in the 1930s, before the term biofeedback was coined, but contains a great deal of background information about the autonomic nervous system. It was Cannon who first identified and named the 'fight or flight' response. Other books on the subject include 'The Relaxation Response', by H. Benson, published by William Morrow, and 'The Stress Of Life', by H. Selye, published by McGraw-Hill.

For the design of biofeedback equipment, a good book to start with is 'The Design Of Electric Circuits In The Behavioural Sciences', by T.N. Cornsweet, published by Wiley.

— Auntie.

THE MIDI INTERFACE



The Musical Instrument Digital Interface (MIDI) standard has been around for quite a while now, but there still seems to be some confusion about its operation and the level of compatibility it offers. In the first of two articles on the subject, Alan Robinson explains how MIDI came about and takes a close look at the hardware.

The use of electronic synthesis has not only brought us a vast new range of sounds, it has also made possible new ways of creating and performing music. As soon as sounds could be created entirely by electronic means, it became possible to link instruments together and control them in ways never previously possible.

The early synthesisers, for example, could be preset to generate a complex sound and then triggered by a foot pedal to produce that sound when required. Better still, the signal from the keyboard of one synthesiser could be used to control both the sound-generating circuits of that instrument and also those of a second instrument such as a string synthesiser. In this way, a musician could use one master keyboard to control a wide range of synthesisers and effects units, removing the need to use several complete instruments.

The advent of electronic memory chips added a further dimension, allowing a series of notes to be programmed into a device known as a sequencer which was then used to control a synthesiser. Bass riffs and other repetitive backing phrases could thus be preset and brought into play at the touch of a button.

Mono-Poly

In the days of monophonic, analogue synthesisers all this could be achieved using just two control signals between instruments, a gate voltage which indicated when a key was depressed and a control voltage which varied with the pitch of the note. The development of polyphonic synthesisers (that is, instruments which can sound more than one note at a time) and the introduction of touch-sensitive keyboards made it necessary to transmit far more information that the gate/CV system could handle. The result, after a period during which different manufacturers adopted incompatible systems, was a general standardisation on the MIDI system.

The standard came about as a result of discussions in 1981 and 1982 involving various musical instrument manufacturers, notably Sequential Circuits (SCI) and Oberheim in the USA, and Roland, Yamaha, Korg, and Kawai in Japan. Its existence was first announced publicly in Robert Moog's column in the October 1982 edition of *Keyboard* magazine.

Key Codes

MIDI is capable of far more than just turning notes on and off. When a key is pressed, 'note on' information is transmitted, with the key number and the key velocity as well. Keyboards which are not velocity sensitive transmit a dummy value half way between the possible extremes. Similarly the 'note off' information transmitted when a key is released also contains release-velocity information, and again, keyboards that are not velocity sensitive transmit a dummy median value. Keyboards that are pressure sensitive can also transmit 'after touch' data, or the force the keys are held down with.

Every time keyboard codes are transmitted, a channel code from one to 16 is transmitted along with the data. The receiving instrument can be assigned to one or a number of these channels, accepting only the codes that are meant for it and ignoring the rest. Other information that can be sent includes pitch bending and modulation, program changes, song selection, real time clocks which allow independent sequencers to synchronise to a common master clock (for example, to allow a synthesizer sequencer and a drum computer to play together) and, as they say, much, much more.

All this information is transmitted in serial form, not unlike the RS232 serial interface used between computers but with a much higher data transmission rate. The meaning of the codes transmitted is standardised to a very large extent so that equipment from different manufacturers is compatible, at least at a basic level of

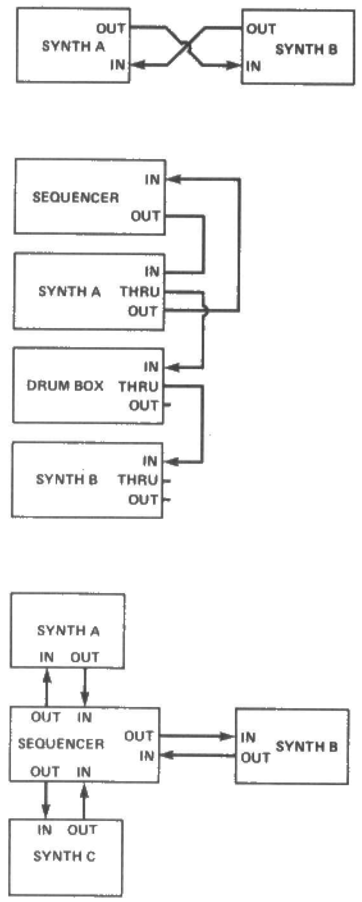


Fig. 1 Some basic configurations of MIDI-equipped musical instruments.

operation. The use of a serial data format also allows low-cost cable and standard DIN connectors to be used for interconnection rather than the expensive multipole connectors and cabling which would be required for parallel interconnection.

You might have heard the term 'MIDI Bus'. MIDI is not really a bus system because each output only goes to one input. However, many instruments are equipped with a MIDI THRU socket which transmits an exact copy of the data received at the MIDI IN socket. This makes it possible for data to be sent over one interface cable to more than one instrument, different channel codes being used to ensure that each instrument only accepts the data intended for it.

Interconnections

The number of configurations possible is not far short of infinite. Perhaps the simplest of all is a set-up where a MIDI keyboard is used to play a separate MIDI synth. Figure 1 shows three more hypothetical examples. The simplest (Fig. 1a) allows synth A and synth B to be played simultaneously from either keyboard. It could also do more, depending on what the two synths are capable of. For example, they might be told not to receive one another's keyboard data. This would make them independent from that point of view, but program selections on both could be changed simultaneously from the controls of just one of them. When the player selects a new program on A, for example, this information is transmitted to B, which then automatically changes its program accordingly. Another possibility is that A might contain a sequencer which could be used to sequence B, which might have no sequencer. Even in this very simple case the possibilities depend very much on the features of the two devices.

Figure 1b is an example of a 'chain' setup in which four devices are connected together. Perhaps the sequencer is being used to control the two synths, with the drum machine playing along. It could be that synth B has to be at the end of the chain because it has no MIDI THRU socket while the other two have. The sequencer transmits keyboard data to be played by synth A over one channel, and for synth B over another, with the drum machine ignoring everything except the timing clocks. The connection from the output of Synth A to the sequencer could be used to record the sequence in the first place. It might be necessary to disconnect this and connect the sequencer MIDI IN lead to synth B MIDI OUT when programming the synth B sequence. Or it might be that synth B has its own built in sequencer, and is only responding to the timing clocks, like the drum machine. The possibilities are virtually endless. All of which again illustrates that the capabilities of a MIDI configuration depend not only on the way the instruments are interconnected, but also on the capabilities of the instruments themselves.

Figure 1c shows another, rather different 'star' set-up. The sequencer in this example has a number of pairs of

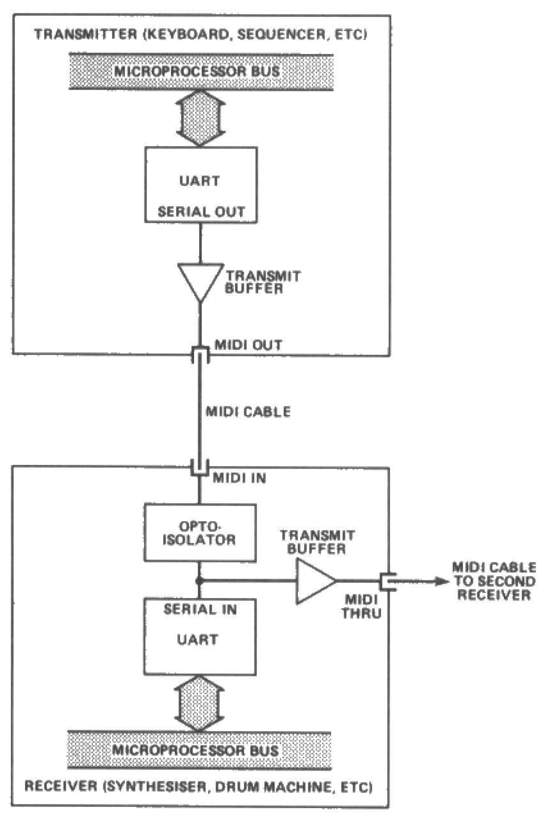


Fig. 2 Block diagram of a typical MIDI system.

MIDI IN and MIDI OUT sockets and can sequence more than one instrument. Perhaps we might also plug a drum box into the MIDI THRU socket on synth B so it can pick up the sequencer's timing clocks and play along. I shan't go any further — obviously it is theoretically possible to interconnect a dozen instruments in some horribly complex 'star' of 'chains' with a few more thoroughly confusing cross connections besides, given the sockets to do it. The only limitation is that the user must be able to understand what it all does!

A BBC Computer operates as a MIDI controller using the Hybrid Technology Music 5000 system.

Hardware

The MIDI interface is built around the same type of serial interface chips as are used in the RS232 system (known as Universal Asynchronous Reciever/Transmitters or UARTs, or alternatively Asynchronous Communication Interface Adapters or ACIAs, but I shall stick to calling them UARTs).

The highest transmission rate of RS232 is 19200 bits per second, but MIDI operates at the even higher rate of 31250 bits per second or one bit every 32us. UART chips can handle this higher bit rate without difficulty. The choice of MIDI baud rate can make the hardware implementation particularly easy because UARTs operate from a clock running at 16 times the baud rate, or 500kHz in this case. This can often be derived from the microprocessor clock by a simple divider.

UARTs can transmit data in a number of formats, but MIDI uses a fixed format of eight bit words with one stop bit and no parity. Each byte transmitted over the interface is in the form of ten successive bits, eight of which are the data. When the transmitter is idle, the UART outputs and inputs are in 'mark' state with a continuous '1' or high output. The first bit of any transmitted byte is the 'start' bit, which signals the beginning of the data byte. Its falling edge is used by the receiver UART as a reference to time the reception of the subsequent bits. After the start bit, eight data bits follow with a bit 0 (the least significant) first. After the last data bit a '1' stop bit follows. If another byte follows immediately this stop bit will be followed by the start bit of the next byte, otherwise the interface will return to the mark state, waiting for the next start bit.

Performing UARTs

There are a number of UARTs which can be used, depending on the application. Readily available types include the 6402, particularly suitable for MIDI circuits not using microprocessors, the 6502-series 6551, the 6800-series 6850, and the 8080/Z80-compatible 8251. All four of these devices will both transmit and receive serial data, so only one is needed for each MIDI IN/OUT combination. There will usually be just one of these per instrument. Microcomputer chips often have UARTs built into them and an external device is not needed.

Figure 2 is a simplified diagram of typical MIDI hardware. It is not absolutely essential that the transmitting and receiving equipment is microprocessor-based, but this is almost always the case in practice so the UARTS are shown connected to microprocessor buses. The serial output from the transmitter UART passes via a buffer to the MIDI OUT socket, which is connected to the MIDI IN socket of the receiver. To avoid hum loops and prevent digital noise getting into audio circuits, an optoisolator is used at the receiving end between the MIDI IN socket and the serial input of the receiver UART.

Optical Solutions

The optoisolator is one of the features which marks MIDI out as a system intended primarily for audio use. It is not needed purely from the data transmission point of view, but eliminates the grounding problems that would almost certainly occur if there were a direct electrical connection between the digital circuits in the transmitter and receiver. Also, the cable is screened but the screen is only grounded at the transmitter end, again to avoid hum loop and digital noise problems. Often the output of the receiver optoisolator will also be connected to a buffer driving the MIDI THRU socket, which then transmits a copy of the MIDI IN data.

Figure 3 shows the serial data buffers, the interface cable and the optoisolator circuit in more detail. The interface cable is ordinary screened twin, with 180 degree 5 pin DIN plugs at each end. Pins 1 and 3 are not connected. The screen is connected as usual to pin 2 and the cores of the cable are connected to pins 4 and 5. Pin 2

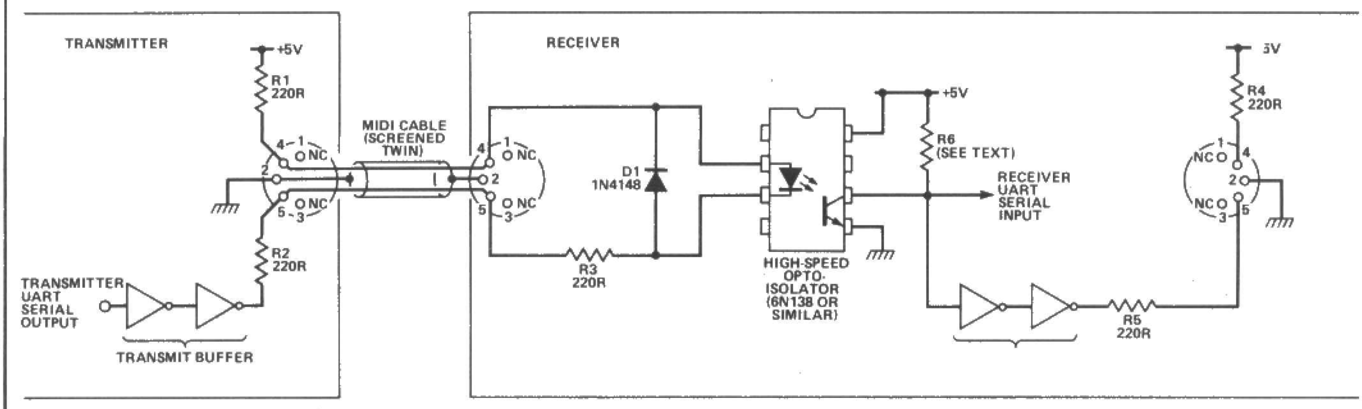


Fig. 3 The major circuit elements of a MIDI transmitter and receiver.

is grounded in the transmitter but left open circuit inside the receiver, while pins 4 and 5 are connected in the transmitter to the driver circuit and in the receiver to the optoisolator circuit. There is no connection between the optoisolator input circuit and any other circuits in the receiver.

R1 and R2 ensure that dodgy leads or incorrect connections cannot damage or short circuit the driver or power supply, R3 limits the current through the optoisolator LED even if an incorrect signal voltage is connected directly to pins 4 and 5, and inverse parallel diode D1 protects it against reverse applied voltages. This arrangement is reasonably idiot proof; although incorrect connections will usually stop it working, they are unlikely to blow anything up. The diagram shows R3 connected between pin 5 of the MIDI IN socket and the optoisolator LED cathode, but it could equally well be between pin 4 and the LED anode, should this be more convenient from a layout point of view. What matters is that the two are in series.

Buffer To Buffer

When the transmitter is idle, or a 'one' bit is being sent, the UART output is in the high state. This puts the output of the transmit buffer in the high state too, and no current flows in the interface. When the UART transmits a 'zero' bit, its serial output goes low and so does the output of the transmit buffer. As a result, a current of about 5mA flows through the loop including R1, the interface cable, the optoisolator input, R3, and R2. This turns on the optoisolator output transistor, pulling its collector low, so that the low output from the transmitter UART is passed on to the receiver UART serial input. When the transmitter UART output returns to the high state, the interface loop current stops, the optoisolator output turns off, and R6 pulls it high and applies a high to the receiver UART input. The output from the optoisolator may also be connected to another transmit buffer if the receiver has a MIDI THRU socket. This is basically the same as the transmit buffer in the transmitter, with R4 and R5 as equivalents to R1 and R2.

The transmit buffers are needed because UARTs are invariably MOS devices which cannot be relied on to sink the 5mA loop current in the low output state. In Fig. 3 the buffers are drawn as pairs of inverters, but in practice almost any logic gate, buffer, or non-inverting combination of gates and buffers capable of sinking the loop current in the low state will do the job. 4000 series CMOS does not have the drive capability, but 74LS or 74HC logic does. Discrete transistors can also be used in place of the second inverter to sink the loop current.

One potential problem with MIDI is that the turn on time of the loop current and optoisolator is generally shorter than the turn off time. Anything that helps speed up the turn-off process can only help, so totem pole outputs are actually a little better than open collector outputs or discrete transistors because they actively pull pin 5 of the interface socket high rather than relying entirely

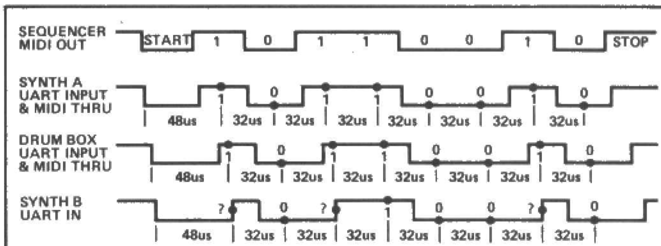


Fig. 4 Timing diagram of a single MIDI byte transmitted by a sequencer.

on the loop current to do so. 74HC logic is particularly good in this respect.

The MIDI THRU socket is intended to pass on an exact copy of the MIDI IN data. In the hypothetical 'chain' set-up in Fig. 1b, the sequencer can transmit data to the three other units by the use of MIDI THRU sockets on synth A and the drum box. By the time the data transmitted by the sequencer has reached synth B's UART it has passed through a total of three interface leads and optoisolator circuits. Unfortunately the loop current and optoisolator generally turn on faster than they turn off, so that the propagation delays of low to high transistions are longer than those of high to low transistors. The effect is cumulative, so that the integrity of the transmitted data is reduced each time it passes through a unit. Obviously there could come a point when the waveform distortion causes data errors.

Figure 4 shows an example of what might happen to a byte transmitted by the sequencer. The point at which a UART samples the input data is timed from the leading edge or high-to-low transition of the start bit, to the nearest sixteenth of a bit period (assuming they are

clocked at 16 times the bit rate). Each bit is sampled at what should be its mid point. The effect of the difference in propagation delays is to delay the low-to-high transitions relative to the high-to-low transitions and shorten the high pulses. When this relative delay, or skew, becomes nearly half a bit period (16us), data errors will happen. In our example here each of the individual units would receive data quite happily from the transmitter, and any combination of two of them would work as well, but the cumulative skew is enough to prevent the last unit from receiving the data reliably.

MIDI Thru And Thru

There is no specification as to how many units can be connected in series, or what an acceptable skew is, though the IMUG MIDI specification does go as far as to say that higher speed optoisolators should be used to avoid these problems with long chain lengths — i.e. more than three instruments. Fortunately it is not difficult to keep skew down to a reasonable level if the optoisolator circuit is designed properly. The MIDI IN and MIDI THRU sockets should not be paralleled to avoid skew altogether. The problem with this is that it means the loop current is shared by two receiver optoisolator circuits (or even more if two or more pieces of gear do the same thing), and the reduced current through each optoisolator could well lead to data errors for that reason instead.

No maximum and minimum levels are specified for the 5mA MIDI loop currrent. Allowing for series resistor tolerances (assuming 5% components), variations in power supply voltage, and possible driver gate and optoisolator LED on-state voltage variations, it is reasonable to assume that the loop current will be somewhere between absolute worst case limits of 3.5mA and 6.0mA, provided of course that the transmitter and receiver are properly designed. In practice the current may be higher because not all transmitter circuits include both series resistors. For example, I have seen a design in which pin 4 of the MIDI OUT socket is connected directly to +5V, not via a series resistor.

A Little Ohm Work

Returning to Fig. 3, the value of R6 must obviously be decided. Its minimum value can be determined by assuming a combination of the lowest loop current and lowest current transfer ratio (CTR) of the optoisolator. The 6N138 is a high speed Darlington optoisolator often used for MIDI interfaces, and has a minimum CTR of at least 300% at the kind of LED current we are talking about. This means that it will be able to sink at least 3 x 3.5mA, or 10.5mA, through R6 in the on state. Provided R6 is 470R or greater, the output is guaranteed to pull low. To keep turn-off time down to a minimum, R6 should be as small as posible, so a value of 470R is a good choice for use with this optoisolator. Typical skews are about 2us.

The 6N136 can also be used, and is a little faster, if used with care. Because it does not have a Darlington output stage, it has a lower CTR of 19% minimum, so a comparatively high 6k8 pull-up resistor should be used.

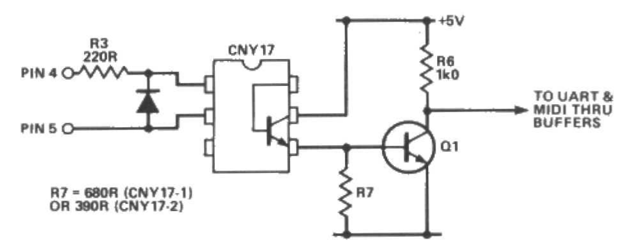


Fig. 5 CNY17 opto-isolator arranged as a non-saturating current switch for optimum performance.

Its speed is sensitive to stray capacitance on the base pin (pin 7), especially between it and the collector pin. This is not a problem on layouts but should be borne in mind if the circuit is built on stripboard — the base and collector will be on adjacent strips unless the strip to pin 7 is cut close to the pin. Also, stray capacitance on the collector pin should be kept low so as not to compromise the rise time. The low-state input current of any logic circuits connected to the optoisolator output have not been taken into account in the calculations of R6 above, but should be if LSTTL is involved.

Saturation Point

The CNY17 is also sometimes specified for the job. It has a minimum current transfer ratio of 40%, so a calculation similar to the one above would indicate that it is guaranteed to sink 1.4mA through R6, and that R6 should therefore be about 3k9. Unfortunately the CNY17 is not particularly fast, and gives poor performance when used this way. One reason for this is that the transistor saturates in the 'on' state, and takes time to recover. Provided saturation can be avoided, the turn on and turn off times of the CNY17 are about equal. In theory it would be possible to avoid saturation by selecting R6 so that the output falls to say half a volt in the low state. This is not really a practical solution, though, because the loop current cannot be relied on to be constant (for example, it could change by connecting to a different transmitter), and the CTR is temperature dependent and slowly changes as the optoisolator ages. This is not a good way to avoid saturation, and should be avoided. Another speed problem is that the collector/emitter voltage changes as the transistor switches on and off, which slows down the switching process due to Miller effect. To get the best performance from the CNY17 it should be operated as a non-saturating current switch with a relative constant collector/emitter voltage. In practice this is not difficult, and Fig. 5 shows how. The optoisolator transistor switches current into the base of the external transistor Q1, which does the job of pulling the UART input low when loop current is on. R7 is calculated so that it takes nearly all of the worst case minimum optoisolator transistor current with Q1 base-emitter voltage across it, the balance flowing into Q1 base and turning it on. The minimum optoisolator current is 1.4mA with the CNY17–1, or 2.2mA with the CNY17–2, which has a higher minimum CTR of 63%. Q1 can be almost any general purpose signal transistor — something like a BC107 or BC182 does admirably. **ETI**

HARDWARE DESIGN CONCEPTS

Mike Barwise fans-out and shows why he's a fan of PAL — it is logically superior when it comes to drive capabilities and propagation.

We saw last month how logic inputs and outputs go high or low by sourcing or sinking current. Outputs sink current when low, and source current when high. Inputs source current when low and sink current when high.

For a given logic state to be passed from an output to the inputs of succeeding devices, the magnitude of the output current and the total magnitude of the currents of all inputs connected to it must conform to certain minimum criteria.

Table 1 shows the typical input and output currents for standard 74 and 74LS TTL logic. A minus sign means that current is flowing out of the device node, which is the case when an input is taken low or an output is taken high. Note that 54 (military) series TTL does not conform to these figures and cannot be considered directly interchangeable in all cases.

There are also several high current output buffer devices, including the familiar 74LS241 through 245, which offer input currents in the same order as the 74LS figures in table 1, but can provide output currents in the order of -15mA (high) and 24mA (low). The importance of these will become apparent shortly.

The drive capability of an output can be considered as the number of subsequents inputs it will take to a defined logic state. This is called fan-out, and is the ratio of the input current to the output current for a given logic state. From Table 1, we see that there is a ratio of 1:20 (high) and 1:10 (low) for standard 74TTL, and a ratio of 1:20 (both states) for 74LS TTL.

This effectively means that standard TTL can drive up to ten of its own family from one output, and that 74LS TTL can drive up to twenty similar devices *under optimum static test conditions*. There are, however, many factors which reduce this capability in reality, at speed.

The Leaky Bucket

The simplest analogy of the dynamics of an input/output combination is a bucket with a hole in the bottom under a stand pipe (Fig. 1). The rate at which the bucket can be filled or emptied depends on the relationship between the flow from the tap and the flow through the hole in the bucket. At the extremes, the bucket will either empty almost completely for good if the flow through the hole is much greater than the flow through the tap (stuck at logic LOW), or try to overflow if the flow through the hole is too small (stuck HIGH). There is quite a wide bracket of hole sizes and tap openings when there will be a drift towards one or other of these extremes.

The ideal condition is where the potential flow through the hole and the tap opening are such as to allow rapid filling of the bucket if the tap is on, and rapid emptying of the bucket if the tap is shut off. By alternately opening and closing the tap, you get a fast — and wet — logic system. This is most easily achieved when both the tap opening and the hole are large, and the overall water flow is considerable. This is a good indication of the reason why very fast logic families (e.g. 74AS and 74F) take lots of current.

Like the filling and emptying of a bucket, the rise and fall times of logic devices depend on the loadings applied to them. It is most unwise to reach (let alone exceed) the maximum loadings calculated above.

Reliability is a very subjective notion...

Working at maximum loadings will allow all sorts of additional effects such as device temperature, socket and interconnection capacitance and so on to become significant to performance, usually in a random manner. Systems which occasionally 'lose' themselves (provided they have an adequate, clean power supply) normally exhibit bad logic design — including local or general overloading.

A safe general rule is to perform the input/output ratio calculation and then halve the answer. Thus a standard 74 TTL output can be considered to be capable of driving up to five similar inputs, and 74LS of driving ten inputs. The same calculation should be performed individually for loadings across the boundary between dissimilar devices: where a 74LS latch drives a standard 74 buffer/gate matrix, for example, as in a floppy disk interface.

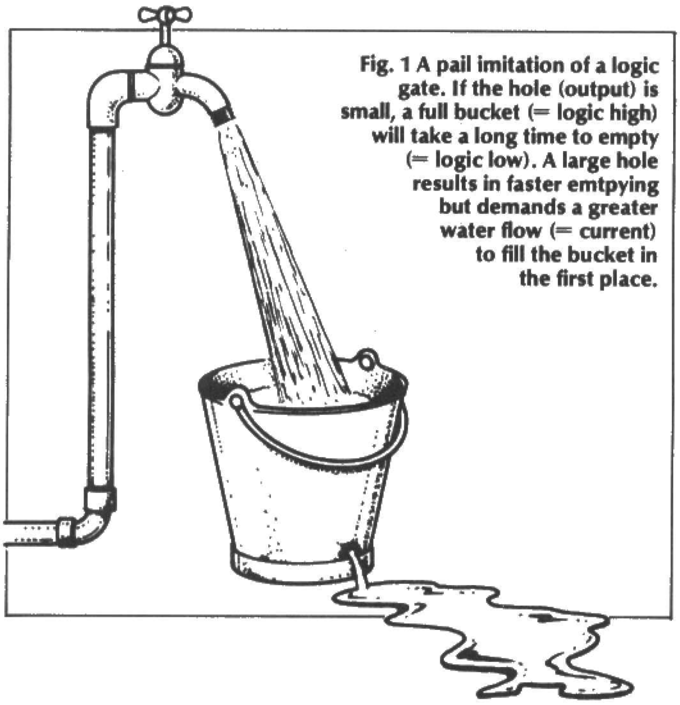


Fig. 1 A pail imitation of a logic gate. If the hole (output) is small, a full bucket (= logic high) will take a long time to empty (= logic low). A large hole results in faster emtpying but demands a greater water flow (= current) to fill the bucket in the first place.

Maintaining Processor Safety Margins

Coming back to our R65C00 processor with its specified drive capability of one TTL load. This means the processor output can sink 1.6mA (low) and source 40μA (high), with the important qualifier, at rated speed.

Interesting point, that. You *can* drive considerably more than this: more than one proprietary design drives in excess of three TTL loads direct from the processor outputs. The snag is that this screws up the processor timings by significantly slowing the transition times of the outputs.

The resultant elimination of the error margin will one day show up for certain: most likely when the user runs the micro for an extended period over a hot summer evening during the time when office and factory workers arrive home. The device temperature and the noisy power supply due to everyone switching appliances on and off right across town will very likely precipitate a crash in the overloaded system, which was just waiting for an excuse anyway.

This brings us back to the problem of reliability. It is a very subjective notion. The school or home amateurs' micro is rarely doing a single job for more than a couple of hours at a stretch, so the statistical chance of a system failure in any work period is pretty low. The same system applied to something like the Mariner space probe would never have got off the ground.

It is worth remembering that Mariner was a ten year old design when last heard of. The parts at the disposal of the designers were much cruder than those we have, yet it worked unfailingly for nearly ten years in one of the most hostile environments ever.

In an extant system, there are some software tricks you can apply to cover hazards, but their effectiveness depends very much on the amount of control at machine level that your machine operating system allows you. When you design hardware from scratch, it should be possible — with care — to come up with quite a simple design with a reliability sufficient for continuous monitoring of non-life support systems for periods of up to a year.

There are systems throughout the world in places like airports and hospitals where people everyday depend on such an order of reliability. It is not uniquely the domain of the expensive supermicro. The home computer enthusiast his been educated to respect a pretty low-grade implementation of available technology.

The microprocessor is obviously a prime candidate for overloading. It requires RAM, ROM, IO device and decode logic all to be coupled to its address and data buses with the lowest possible propagation delays.

Every logic device has a finite delay between the application of an input and the corresponding change in output. These are added together when devices are cascaded (see my article in ETI, October 1986) and must be taken into account at the secondary design stage. It is obviously pointless to minimize processor bus loading and then add a delay due to signal propagation nearly equal to the time saved.

Silicon to the Rescue

Fortunately, the silicon designer is on our side here: a static RAM of 8K by 8-bits loads the bus only about half as much as an earlier 4K by 1-bit RAM, and the loadings imposed by almost all EPROMs from 1K to 32K (NMOS) are effectively equal.

There is, of course, a trade-off in flexibility in using larger devices. I consider an 8Kx8 about the optimum for use in eight bit systems — it allows subsequent amendments to the firmware/user RAM ratio without undue wastage of valuable address space.

The same system applied to something like the Mariner space probe would never have got off the ground...

The real crunch comes in high performance subsystems — where special functions are implemented in MSI or LSI logic — and in the decoding of complex address maps — where, until recently, TTL was the prime candidate.

The most common procedure in complex systems has generally been to insert buffers at the processor, thus increasing the bus drive capability to the -15/24mA level. However, in a great many low cost micros, only the DATA and ADDRESS lines are thus buffered, leaving the clock and control bus (READ, WRITE and so on) open to overloading.

New developments such as CMOS logic with 74LS TTL function (and speeds of the same order) and Programmable Array Logic (PAL) allow designers to maximize 8-bit micro performance to a level where it vies with the flashy fashionable 16-bit systems. Sadly, few consumer micro manufacturers have taken the trouble, but in the micro-controlled testgear field, the performance increases are beginning to show.

A Constant PAL

Of these developments, the most useful is PAL. CMOS logic suffers from the same kind of problems as bipolar, in a different order of magnitude. Output drive capability depends on input loading.

The beauty of PAL is that no matter how complex the internal structure of the logic, the input and out-

put loadings are constant for a given device. This has the same benefit as the larger EPROM, and there are effectively no trade-offs.

PAL consists of a fully interconnected array of logic gates with fusible links at the interconnections. A raw PAL does nothing, as the interconnections cause cancellations internally. If you blow away the bits you don't want, you can create almost any configuration of logic on the piece of silicon.

There is a range of raw devices providing different matrices of gates and latches/registers, and the main limitation to date is the pinout: the number of possible inputs and outputs, which is currently a mechanical constraint of the DIP package.

In the PAL, sets of high current buffers separate the input pins from the logic matrix, and the logic outputs from the output pins. The result is as if you had interposed one of the 74LS TTL buffer chips between the outputs and the succeeding inputs of your heavyweight logic matrix, except that the propagation delay of the buffers in PAL is very much less, due to their proximity to the rest of the circuit on the same piece of silicon.

Overall propagation delays are very much shorter, too, compared with the discrete TTL version of almost any medium complexity circuit, so the PAL really wins all round.

PALs are usually blown from a set of Boolean equations optionally accompanied by a truth table for verification, and quite a number of suppliers will now perform this service for a small charge. They are not really economic for one-offs, unless you happen to have programming equipment, but quantities of five or more begin to be cost-effective if blown from a master device.

An example of the benefit is the decoding of an address map similar to the BBC Micro. The map is decoded into 8K slots for RAM and ROM, but there is a 512-byte hardware window at the bottom of the top 1K (page &FC page &FD). The 8K slots are easy: a 74LS138 decoder driven from the top three address lines, but the window starts to cause problems.

The top 8K must be sub-divided into 356 byte pages, and two of them tapped off for hardware decoding. The remainder of the space is occupied by ROM, so either the other page decodes must be recombined (messy) to enable the ROM, or the two hardware pages must disable the ROM otherwise selected by the top 8K decode. Additionally, a signal must be output while the hardware space is selected, to slow the system clock. Either way, quite complex logic matrix must be created. My first version used about six 16-pin and 14-pin chips.

A single 24-pin PAL can perform all the required functions and still has the spare capacity to allow up to three alternative user-selected address maps.

As you can see, I am pretty enthusiastic about PAL, and I will be saying more about it in this series. It actually allows the addition of features to the eight-bit micros which have previously been considered solely the domain of 16-bit and 32-bit processors.

	74	74LS
IN HIGH	40μA	20μA
OUT HIGH	-800μA	-400μA
IN LOW	-1.6mA	-0.4mA
OUT LOW	16mA	8mA

Table 1 Typical input and output currents for 74 and 74LS TTL.

ETI

FM FROM THE BEGINNING

John Linsley Hood continues his short series on FM transmission and reception with a look at the requirements of FM receiver design.

Last month I looked at the way in which the left and right channels are encoded before transmission as a stereo FM signal and at the performance limitations this process involves. In this article I will be looking at the design of VHF/FM receivers and the influence the receiver circuitry has on the quality of the final audio signal.

Figure 1 shows a typical FM receiver circuit in block diagram form. The RF, mixer and oscillator stages (the 'front end') are usually grouped on a small PCB mounted in an individually screened metal box, and this tuner unit is often made by some outside specialist manufacturer who supplies several different hi-fi companies.

Tuning System

In the earlier days of FM, such head units were usually tuned by two or three-gang air-spaced variable capacitors. Nowadays varicap tuning diodes are almost always employed, except where the unit combines AM and FM in which case a variable capacitor may still be employed. This is because the large values of tuning capacitance required for use on MW and LW are difficult to obtain with varicaps.

Varicap diodes are basically reverse-biased silicon diodes having a fairly large, heavily doped, PN junction area. This provides a useful junction capacitance which can be varied by an external control voltage. Apart from cheapness, the advantages of varicap diodes are that they allow a greater number of tuned stages, they allow the tuning capacitors to be placed nearer to the coils, and they allow remote (possibly computer controlled) tuning.

The snags are that varicap diodes have a greater RF loss factor than air spaced capacitors and this spoils the Q of the coils (though this probably doesn't matter very much at VHF where pre-mixer selectivity isn't very important). They also suffer from a temperature drift of capcitance — even for a constant tuning voltage — and the tuned frequency may be modulated by the RF voltage appearing across the tuned circuit if the signal is large enough. Twin varicap units of the type shown in Fig. 2 cost a bit more but are much better in this respect, and are used in better quality units.

RF Devices

In inexpensive tuner heads, the amplifying devices are usually bipolar junction transistors. These are still the best choice at frequencies over 1GHz or so, although gallium arsenide MOSFETs are challenging this position.

The main snag with bipolar devices is that they do not provide a good match with the high impedances of the tuned circuits, and this loss of power gain tends to degrade the noise performance of the stage. They are also very non-linear, which makes the head unit more susceptible to cross-modulation in the presence of strong input signals.

The best device in terms of noise figure and linearity is the junction FET, but these also suffer from too high a value of internal (drain/gate) feedback capacitance, and

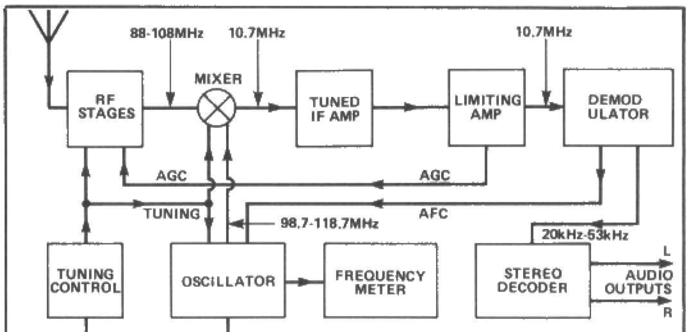


Fig. 1 Block diagram of a typical modern FM tuner.

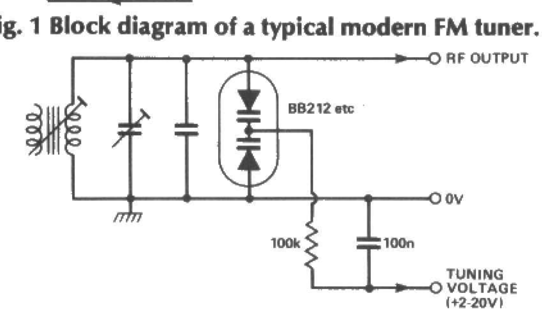


Fig. 2 Tuned stage using a twin varicap diode.

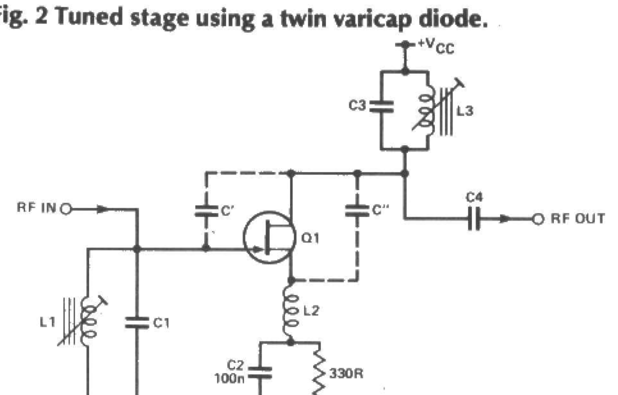


Fig. 3 The use of a small inductor in the supply lead to neutralise an FET stage.

if this is not neutralised it will lead to poor tuned circuit performance and RF instability.

A very neat way of neutralising an RF FET stage is shown in Fig. 3. In this, a small inductance is formed in the PCB track leading to the source of the FET, and if the inductance is chosen so that

$$C'' \times L2 = C' \times L1$$

(where C' is the internal feedback capacitance, and C'' is the drain source capacitance) then the effect of the internal capacitative feedback will be neutralised and the stage will be stable.

In typical junction FETs, the value of C'' is about 10x C', so the inductance of L2 will not need to be very big for amplifiers working in the 100MHz range.

Although they are not the quietest or the most linear of the available transistor types, dual gate MOSFETs are the easiest devices to use because they have very low internal capacitance between the drain and gate 1, permitting stable operation at RF. They also have a second (screening) gate which can be used for automatic gain control (AGC) purposes.

For mixer use, the second gate on a dual gate MOSFET provides a useful point for local oscillator injection, as shown in the circuit layout of Fig. 4a. More up-market tuners might use a double balanced mixer circuit based on a pair of junction FETs, as shown in Fig. 4b.

The main concern at this stage is freedom from cross modulation by strong unwanted adjacent channel signals — an important feature for those who live near to transmitters — and good sensitivity and signal-to-noise ratio, which is important for those who live further away from the programme source.

Having two or three tuned circuits between the RF amplifier and the mixer input also helps to reduce the problems of cross-modulation. A good quality tuner head based on dual gate MOSFETs might have the circuit layout shown in Fig. 5.

Bipolar transistors make quite good local oscillators, though it is good practice to buffer their outputs with a pair of junction FETs — one to the mixer, the other in the line to the frequency meter.

In presenting these comments on the design of tuner front ends I am not aiming to encourage DIY enthusiasts to design and build their own. Although I do not think there is any particular magic involved in the design of such units, the layout is critical if complete stability is to be achieved. For this reason it is usually better to purchase a commercial unit ready-built. These notes should help you choose a good one, particularly if you can examine the circuit diagram of a tuner unit before purchasing.

Selectivity

FM tuners, like almost all other modern radio receivers, employ the superhet principle. The incoming signals are converted by a frequency changer stage down to a fixed intermediate frequency (IF) at which the bulk of the RF amplification is obtained, along with all of the adjacent channel selectivity.

The convention for VHF/FM tuners is that the IF is 10.7MHz, and the most common method of obtaining the required selectivity is by way of ceramic surface acoustic wave (SAW) filters.

There isn't room here to describe in detail how these devices work (see ETI November 1985 — Ed.) but basically they consist of two transducer elements deposited on the surface of a piezo-electric material. Applying an input signal to one of the transducers causes a physical ripple to be launched across the surface of the chip where it is received by the second transducer and converted back into electrical energy. By careful design

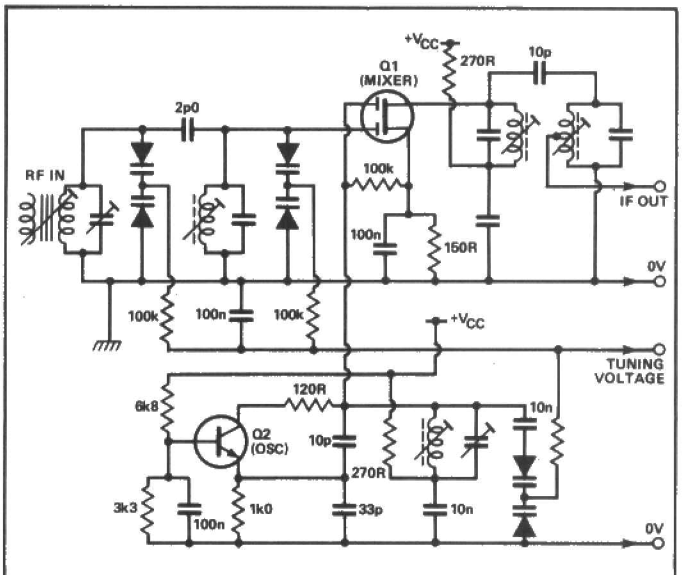
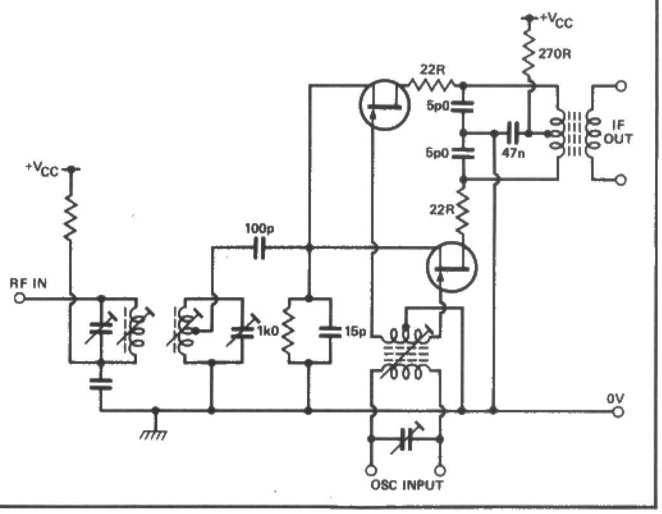


Fig. 4a (above) an FM mixer stage using a dual-gate MOSFET, and Fig. 4b (Below) a balanced mixer system using junction FETs.



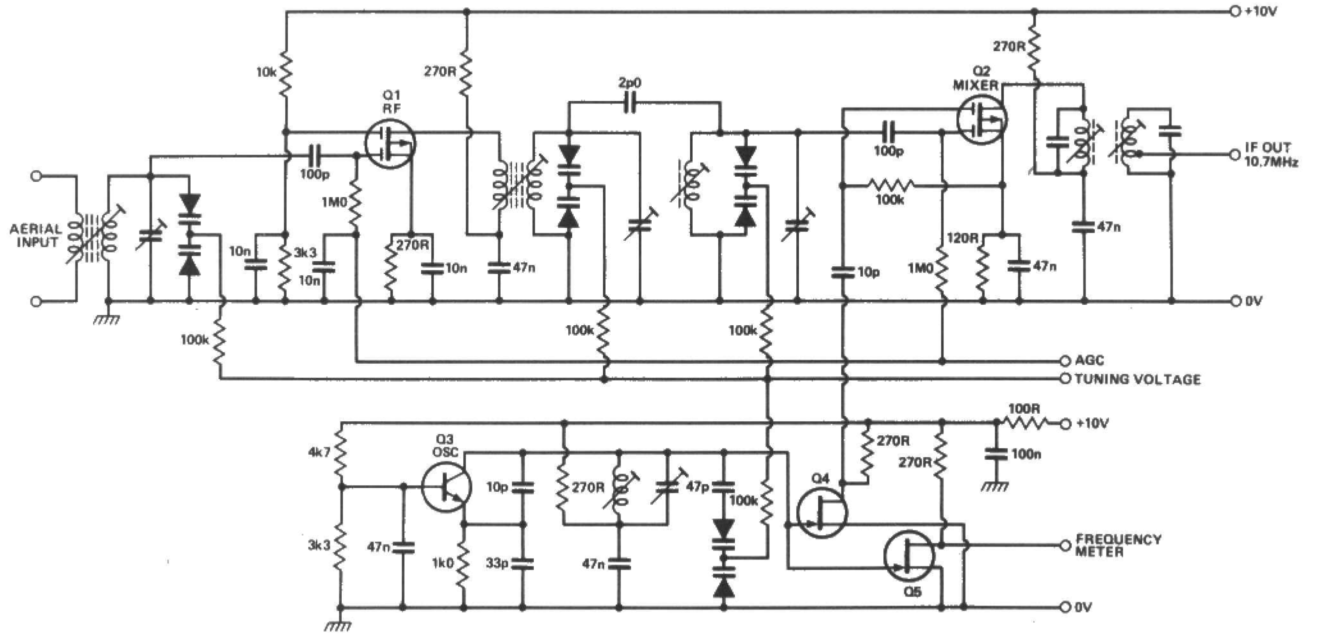
of the physical shape of the transducer elements, it is possible to define frequencies at which the surface waves will combine constructively and others at which they will cancel. In this way a near-ideal filter characteristic can be produced. A typical SAW filter pass-band response is shown in Fig. 6.

An important advantage of SAW filters is that they allow the relative phase shift of the signals to be determined independently of the RF pass-band shape. This relative phase shift is important for low distortion, and is usually called group delay.

The snag with SAW filters is that they invariably introduced a substantial loss of signal strength, typically 10x, and they must be driven and terminated with a low impedance, usually 300 ohms. Often the tuner head will have an output impedance of the right order to drive a filter, but either an RF IC or a transistor will be needed between stages to make up for the signal loss.

A typical circuit for an input IF stage is shown in Fig. 7. A high degree of selectivity is essential in order to avoid multiple signals causing cross-modulation in the limiting IF stage. For this reason, two pairs of SAW filters are often used in series. However, too much selectivity will spoil the stereo image separation in the recovered audio signal, so a degree of compromise is required.

Fig. 5 Circuit diagram of a typical high quality receiver 'front end'.



The Limiting IF Stage

In the FM transmission system, the amplitude modulation characteristics of the signal are not of interest — indeed, the idea is to get rid of them, to suppress impulse type noise. One of the benefits of this is that the final IF stage can be designed to have a high gain so that it clips the signal to a fixed and constant output level.

In contemporary practice this is always done by a specialised type of IC which also contains the FM demodulator, and probably a range of other useful bits and pieces of circuitry as well.

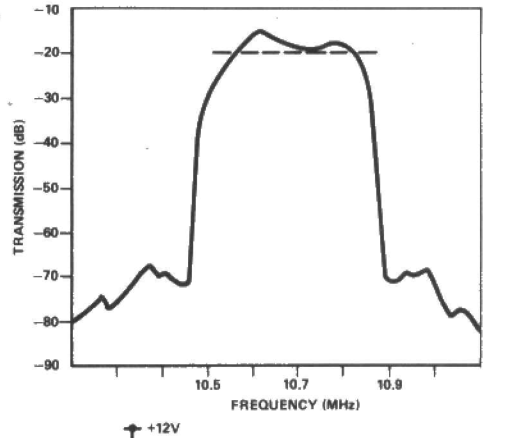
In the earlier ICs of this type designers took advantage of the ease with which bipolar transistor amplifier stages could be incorporated. In the Texas SN76660N, for example, no less than six push-pull gain stages were used before the demodulator, as shown in Fig. 8. Since the collector-emitter voltage on each of the amplifying stages was held to the same value as the base emitter voltage of the following stage (about 0.6V), this caused the amplitude of the RF signal to be limited to a peak level of the same value.

The penalty is that the gain from each stage is low, and a lot of stages will be needed if a clipping level input sensitivity of 20uV or so is to be achieved. In consequence, the cumulative transistor noise is quite substantial.

Later designs, such as the Motorola MC1351 or the TAA930, interposed an emitter follower between the succeeding stages, as shown in Fig. 9. This raised the load impedance for each amplifying stage, increasing the individual stage gain and allowing the number of amplifying stages to be reduced to three for the same input sensitivity. The result was a substantial improvement in the overall signal-to noise ratio.

The latest step in the development process came with the introduction of the RCA CA3089E/3189E ICs. These use a fully symmetrical push-pull amplifier system (as used in the TI SN76660N IC but dropped in the 1351 and its derivatives), an input series-connected transistor cascode arrangement which provides the best possible input stage gain and noise figure, emitter-follower load buffering in each stage for high gain, and a pair of back-to-back diodes at the output to give a clean, symmétrical, limiting chracteristic. This is a rather better way of limiting than simply letting the amplifying stages run up against their supply voltage limits.

Fig. 6 Transmission characteristics of a typical 10.7MHz SAW filter.



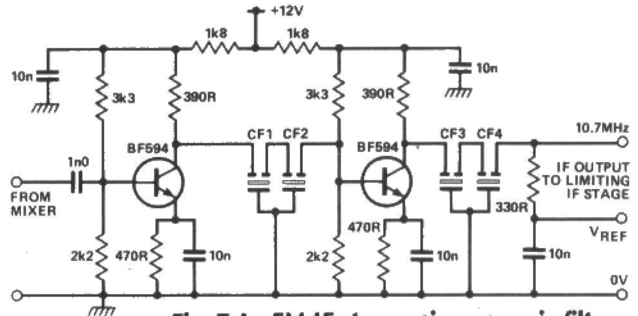


Fig. 7 An FM IF stage using ceramic filters.

The 3189E is very similar in circuit layout to the 3089E, but a few small detailed design improvements have been included, mainly aimed at reducing still further the background noise level. This IC (and copies of it made by other manufacturers), is deservedly the most popular device for use in FM limiting amplifier stages. A slightly simplified circuit diagram of the limiting amplifier chain is shown in Fig. 10.

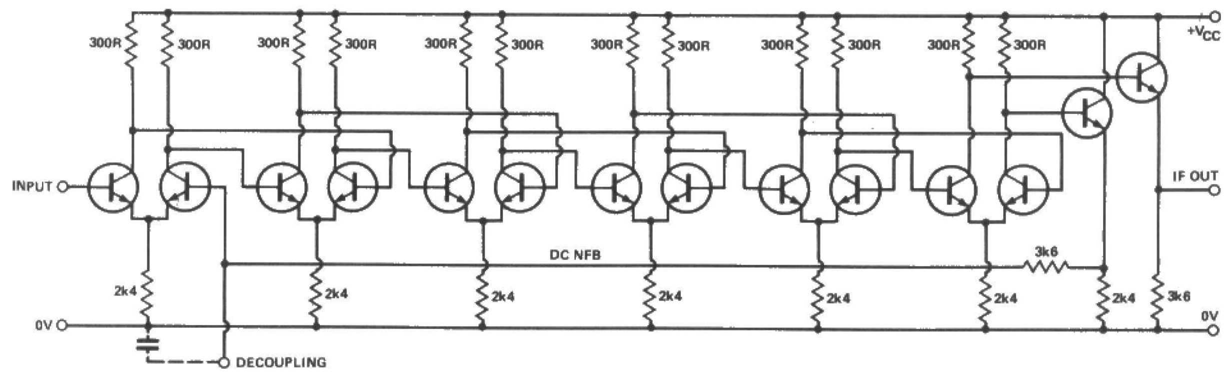


Fig. 8 The limiting IF amplifier circuit used in the Texas SN76660N.

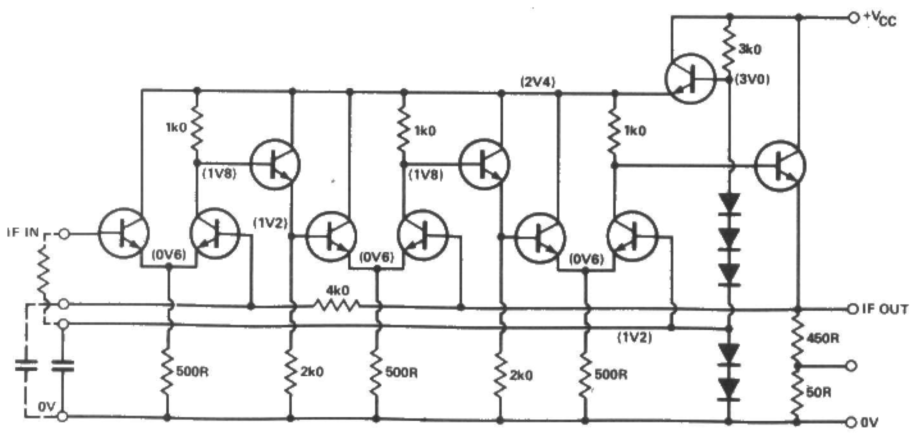


Fig. 9 The limiting IF amplifier circuit used in the MC1351 and TAA930 ICs.

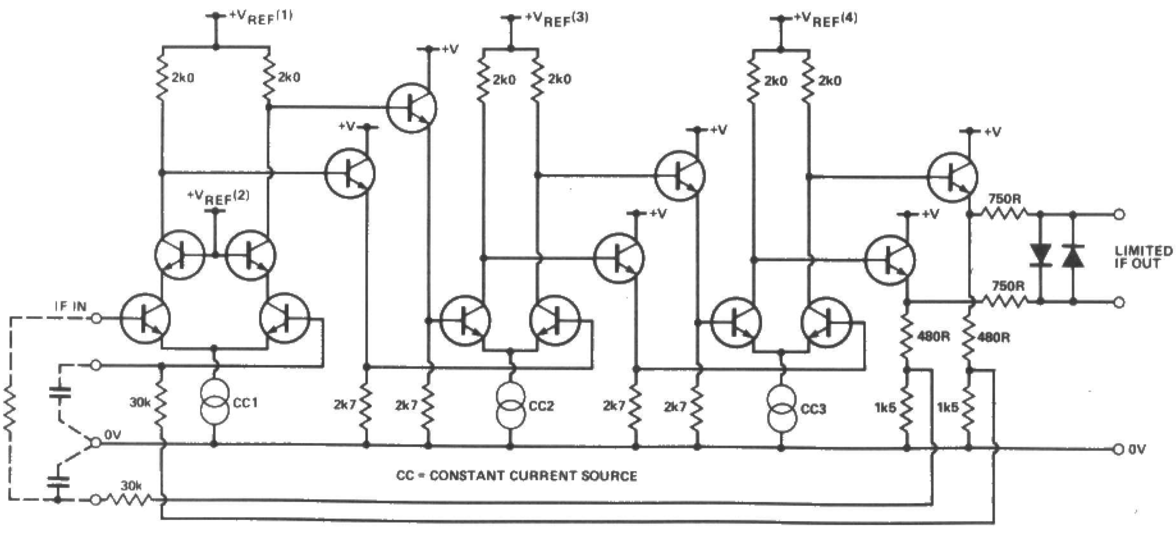


Fig. 10 The limiting IF amplifier circuit used in the RCA CA3089/3189 (simplified for clarity).

The Demodulator Stage

This is the key stage in the FM tuner. It determines the freedom from distortion of the recovered audio signal, the rejection of intruding AM-type noise (motor car ignition interference and the like) and the capture ratio of the receiver.

This last term refers to the ability of the receiver to reject an interfering FM signal that it is less strong than the wanted one, even if it is on the same frequency. This rejection is expressed in dB: a value of 1dB is excellent, while 3dB or greater would nowadays be thought to be a very poor rejection ratio indeed.

The earliest of the specifically-designed FM demodulator circuits was the 'Round-Travis' circuit shown in Fig. 11a. This consists basically of a pair of tuned circuits with associated diode detectors, one tuned above the centre frequency and arranged to give a positive-going output while the other is tuned below the centre frequency and has a negative-going output. When these two signals are combined, the result is as shown in Fig. 11b.

This layout gives no AM rejection except for signals occuring precisely at F_o, and its linearity depends entirely on the shapes of the response curves of L2C1/

L3C2 and the skill with which one tunes these two circuits.

The early circuits were gradually replaced with demodulators of the phase detector type. These fall under three headings, the Foster-Seeley, the Ratio Detector and the Gate Coincidence Demodulator type. All rely on the fact that if an RF signal is applied to a tuned circuit at a frequency which is below the resonant frequency of that circuit (F_o), the tuned circuit presents an inductive load and the phase of the voltage leads that of the current. On the other hand, if the RF signal has a frequency above F_o, the tuned circuit looks like a capacitance and the phase of the voltage lags behind that of the current.

In the case of the ratio detector layout shown in Fig. 12a (and the Foster-Seeley circuit operates in a very similar manner) a small third, untuned, winding on the RF transformer is arranged to inject a signal into the centre tap of the secondary.

Since the two rectifier diodes are connected in opposition, there will normally be no AF output at this centre tap point at any frequency. However, if the input RF frequency is either above or below F_o, the signal from L3 will add to that in the upper half of L2 and subtract from that in the lower, or vice-versa, as the phase of the voltage across L2 changes. The result will be an output response of the form shown in Fig. 12b.

This was the most popular type of FM demodulator circuit until about fifteen years ago, since when it has been almost entirely replaced by IC-based systems using gate coincidence techniques.

Gate Coincidence Demodulators

Gate coincidence demodulators use the transistor layout shown in Fig. 13. The current from the constant current source CC1 is shared between the transistors Q1 and Q2, then divided again between transistors Q3-Q6 and finally recombined in the load resistors R1 and R2.

Obviously, if all the transistors are indentical and V_{in} (1) is the same as V_{ref} (1) and V_{in} (2) is the same as V_{ref} (2), the output current through R1 will be the same as that through R2. Moreover, because of the cross-connection of Q3-Q5 and Q4-Q6, a change in the potential of V_{in} (1) or V_{in} (2) will not alter this situation, provided that it does not occur at both inputs simultaneously.

However, if both V_{in} (1) and V_{in} (2) were to go positive simultaneously, the current through R1 would increase and that through R2 would decrease, causing a positive-going output change at point B. On the other hand, if V_{in} (1) were to go positive while V_{in} (2) were to go negative, the output voltage at B would be negative going.

This allows the circuit to be used as an FM demodulator in an arrangement of the kind shown in Fig. 14. If the IF signal from the limiting amplifier LA1 is taken to point E and a small amount of this signal is used to drive a tuned circuit connected across points C and D, then, as the input frequency varies with respect to the natural resonant frequency of L1/L3, so the phase of the signal applied to point C will alter and the output at B will change.

The linearity of the audio output from this type of demodualtor can be very good, but the AF output and signal-to-noise ratio decrease if the quadrature input from L1/C3 gets smaller. For this reason, the coupling capacitor C2 must not be small, but then again it must not be so big that it swamps the input at C. Also, the performance of the circuit is better if the Q of L1/C3 is high, but it most not be so high that this circuit cannot ade-

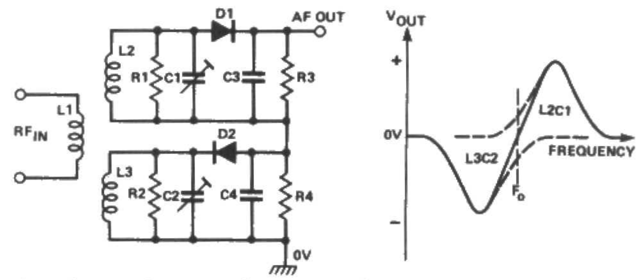


Fig. 11 The circuit and output voltage/frequency characteristics of a Round-Travis FM detector.

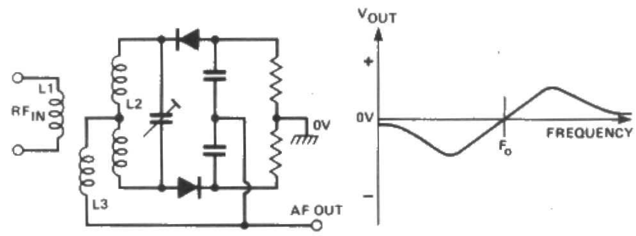


Fig. 12 The circuit and output voltage/frequency characteristics of a ratio detector.

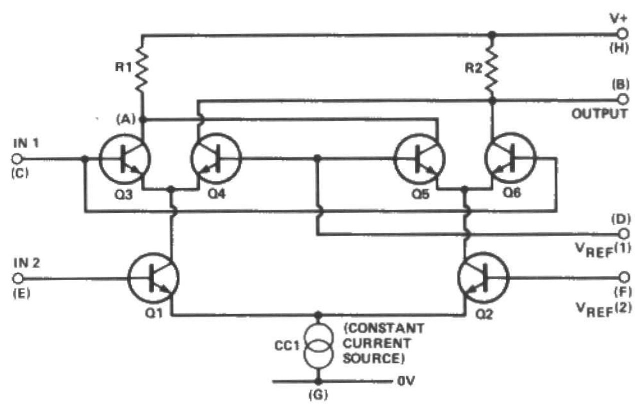


Fig. 13 A transistor gate-coincidence array.

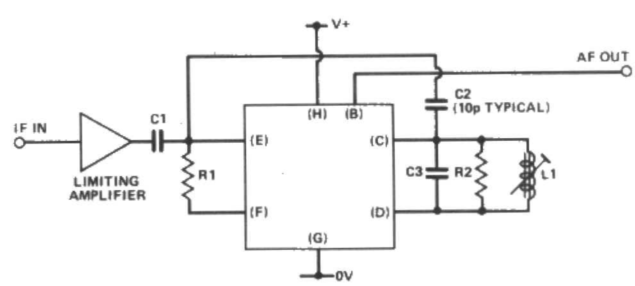


Fig. 14 Using a gate-coincidence detector for FM demodulation.

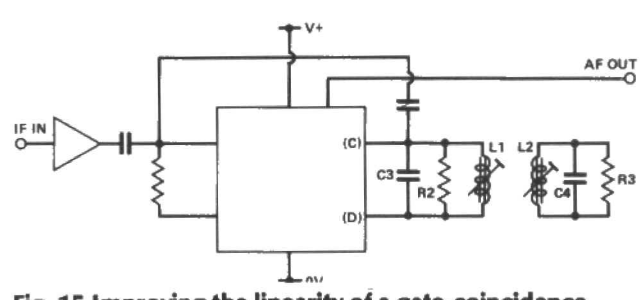


Fig. 15 Improving the linearity of a gate-coincidence demodulator by means of a band-pass quadrature circuit.

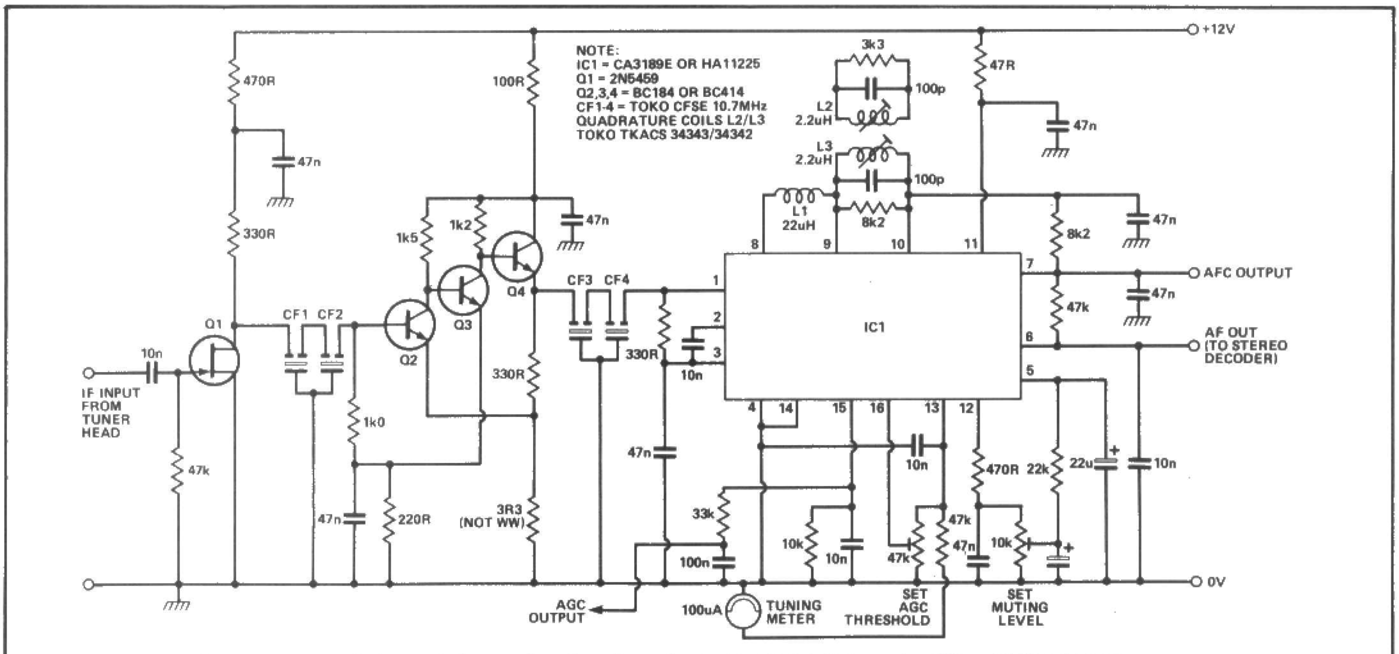


Fig. 16 A complete FM IF and demodulator circuit using the RCA CA3189E or the Hitachi HA11225.

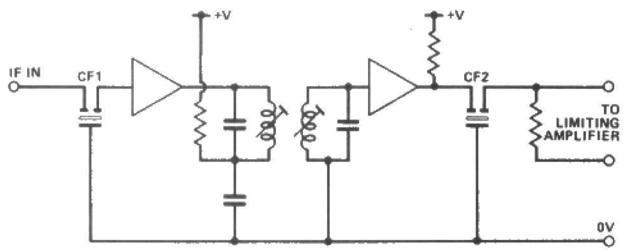


Fig. 17 Arrangement for group delay compensation in an IF amplifier.

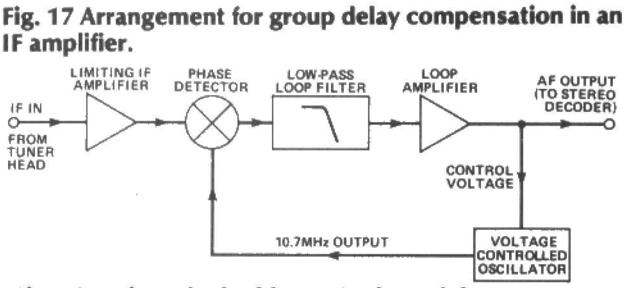


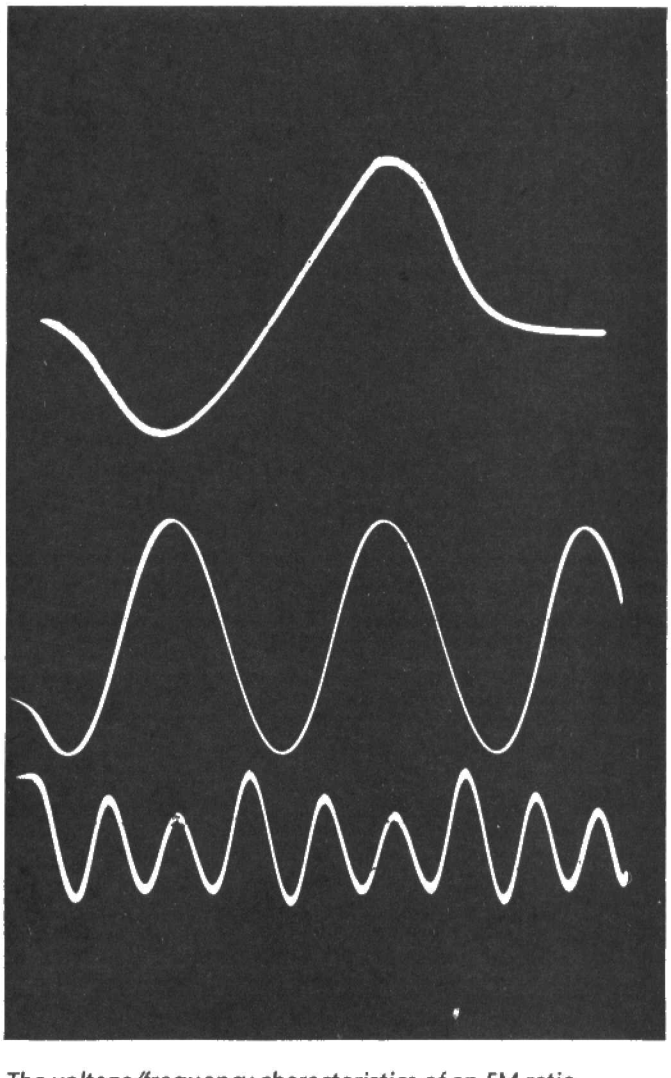
Fig. 18 A phase-locked-loop FM demodulator system.

quately cover the required FM IF bandwidth (±150kHz or so).

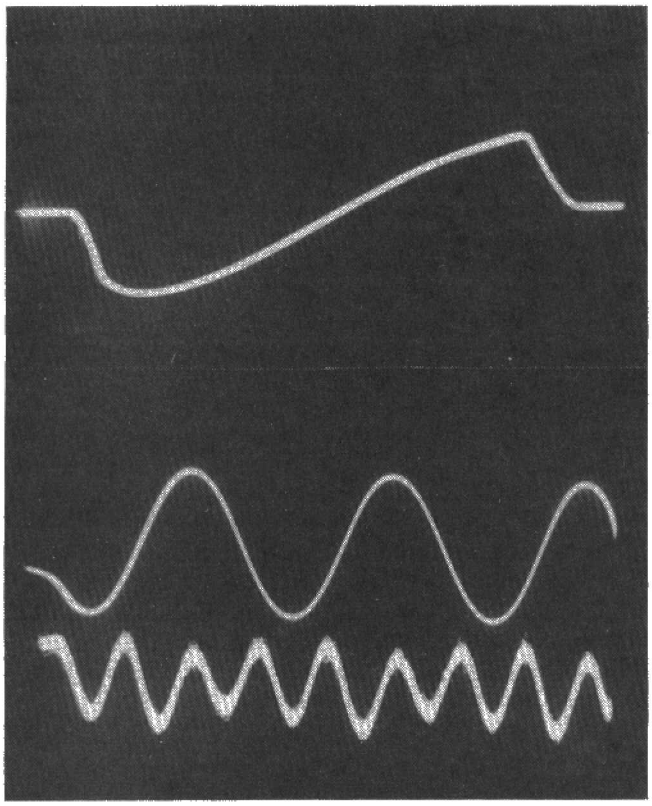
A useful improvement in performance is given if L1/C3 is elaborated to a bandpass coupled pair of circuits, as shown in Fig. 15. This allows both L1 and L2 to have higher values of Q without impairing the usable bandwidth. A complete FM IF layout based on a CA3189E and a double-tuned quadrature coil system is shown in Fig. 16.

THD values down to 0.1% have been claimed for this particular demodulator configuration, as compared with 0.3-0.5% for normal, single coil systems.

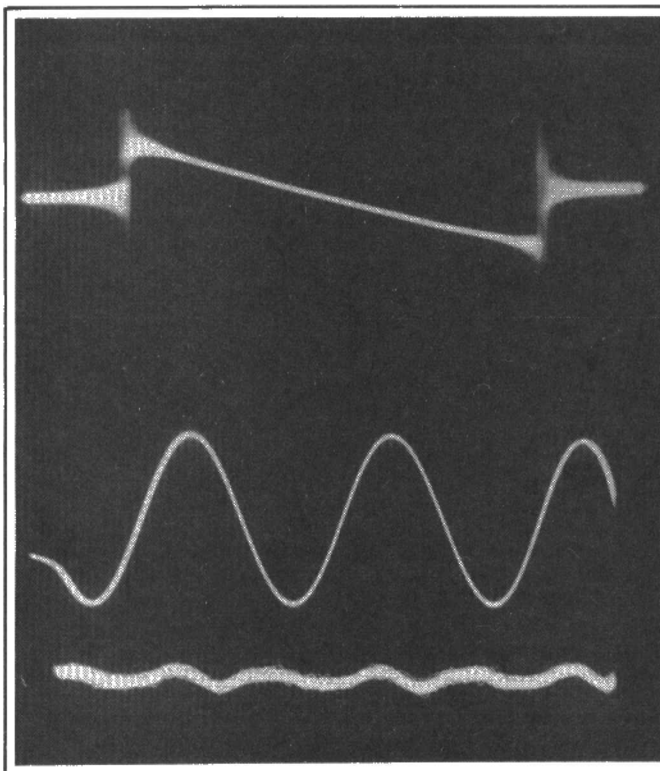
However, although the demodulator system on its own might give values of this kind, any phase-sensitive demodulator system (including the Foster-Seeley, the ratio detector, and the gate-coincidence system) will be influenced by the frequency/phase relationships imposed by preceding amplifier stages, RF coils, ceramic filters and like. So, in practice, the final result will never be quite as good as the figures claimed by IC manufacturers.



The voltage/frequency characteristics of an FM ratio detector and the resultant 1kHz demodulator harmonic distortion (about 1.2%).



The voltage/frequency characteristics of an FM gate-coincidence detector circuit (single coil type) and the resultant 1kHz demodulator harmonic distortion (about 0.6%).



The voltage/frequency characteristics of a phase-locked-loop FM demodulator and the resultant 1kHz harmonic distortion (about 0.15%).

A simple circuit arrangement which is used commercially to compensate for the errors in the group delay characteristics of ceramic filters, and thereby to improve the overall THD figure of the receiver, is shown in Fig. 17. In this, advantage is taken of the fact that the phase characteristics of bandpass-coupled tuned circuits tend to be similar to those of ceramic filters but opposite in sign. The combination of these two kinds of elements therefore tends to cancel the phase error.

The influence of the frequency/phase characteristics of preceding stages also explains why it is very important that incipient instability in the RF or IF tuned circuits must be avoided. It can have a drastic effect on the phase linearity and the final THD of the whole receiver system.

Other Demodulator Systems

In view of the dependence of phase detector systems on the phase linearity of the preceding stages, it is surprising that so little commercial interest has been shown in the alternatives, of which the two most promising are the phase-locked loop (PLL), and the pulse counting system.

In both of these cases the output signal voltage is related directly to the incoming signal frequency, and the demodulator linearity is inherent in itself rather than dependent on the performance of the preceding parts of the system.

The phase-locked loop in particular is a very elegant way of demodulating an FM signal, but is seldom if ever used even though a PLL arrangement is commonly employed in the stereo decoder section.

The basic layout of a PLL FM demodulator is shown in Fig. 18. In this the incoming 10.7MHz IF signal from the limiting amplifier is fed to a phase detector along with the output from a linear voltage controlled oscillator. The phase detector can have the kind of circuit layout shown in Fig. 13. Its output (which will consist of the sum and difference frequencies of the two input components) is passed through a low-pass filter and an amplifier (if needed) to form a control voltage for the VCO.

If the VCO pulls into lock, this control voltage will swing up and down as required to force the VCO to stay in frequency synchronisation with the incoming signal. The control voltage, as fed to the VCO, will be as linear an equivalent of the signal modulation as the characteristics of the VCO allows.

The benefits of such a demodulator system are clearly shown in the three photographs which were taken directly off the screen of an oscilloscope. They show various types of FM receivers driven at their aerial inputs by a frequency modulated oscillator. The actual harmonic distortion of the recovered signal for a 1kHz sinewave-modulated input is also shown.

In the case of the two phase detector systems, the linearity of the demodulator itself would have been somewhat better than is shown: a good part of the final distortion is due to the inadequacies of the preceding stages.

In the next part of this series I will describe a practical PLL FM demodulator system having a very high linearity, and I will also look at the problems presented by the stereo decoder stage of the receiver and some possible solutions.

ETI

RGB-COMPOSITE CONVERTER

Got RGB? Need composite? Dan Ogilvie has this neat solution for you — and it's far from discrete.

Until fairly recently a discrete solution to colour encoding had to be used. Perhaps the most popular circuits used the LM1886. This National Semiconductor IC accepts a 3-bit digital code for each of the R, G and B inputs which limits the number of available colours to 512 ($2^{(3\times3)}$), although this is usually adequate. Some support chips are required; for example the half line frequency generator (7.8kHz) for the 90° PAL phase shifting.

Our design uses a Motorola IC, the MC1377P, accepts true analogue or digital inputs for encoding and provides a direct composite video output. It's a circuit taken more-or-less directly from the applications notes published by Motorola and may be useful for owners of QL, Spectrum+2, Commodore 128 and other computers with RGB but no composite output. Composite monitors are generally cheaper and easier to come by.

The IC

The 20-pin MC1377P (see Fig. 1) contains all that is necessary to perform good quality colour encoding to either PAL or NTSC standards (Fig. 2). The incoming RGB inputs are AC coupled into pins 3, 4 and 5 (Fig. 3). Each input requires 1V peak-to-peak to achieve colour saturation and gives an output with a luminance bandwidth of 8MHz, comfortably exceeding the broadcast TV standards.

The Inputs are fed to the colour difference and luminance matrix which generates the luminance (brightness-Y) and the colour difference signals — (R-Y) and (B-Y) — according to the colour equation Y=0.3R+0.59B+0.11G.

The matrix outputs are clamped to the back porch (reference black) by sync driven clamp. The IC requires a negative going composite sync input. This must contain the correctly serrated sync pulses within the field pulse for proper operation of the internal PAL flip-flop (which generates the half line frequency). The sync input can be driven directly from TTL or CMOS. The IC also generates the burst gate pulse from the sync input.

The colour burst is obtained from a Colpitts oscillator on pins 17 and 18. Alternatively a burst may be lightly coupled in to lock the oscillator or it may be displayed completely and driven from an external source.

The oscillator output provides the reference to the B-Y modulator and is also fed to a voltage controlled 90° phase shifter which provides the reference for the R-Y modulator. By allowing the 90° phase shifter to be voltage controlled, fine tuning of the phase shift may be achieved by a pot on pin 19. Without this, the phase shift is guaranteed at ± 3°. This phase shift affects the hues of the picture.

The output of the R-Y modulator is fed to a 180° phase shifter which is switched in and out at the half line frequency. This is fed, together with the B-Y

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Supply Voltage	V_{CC}	15	Vdc
8.2 Vdc Regulator Output Current	I_{REG}	10	mAdc
Operating Temperature	T_{AMB}	0 to −70	°C
Storage Temperature	T_{stg}	−65 to −150	°C
Junction Temperature	$T_{J(max)}$	150	°C
Power Dissipation, package Derate above 25°C	P_D	1.25 10	W mW/°C

RECOMMENDED OPERATING CONDITIONS

Supply Voltage	12 ± 2	Vdc
Sync Tip Level Sync, Blanking Level	−0.5 to −1.0 −1.7 to +8.2	Vdc
Red, Green, Blue Inputs (Saturated)	1.0	V_{p-p}

ELECTRICAL CHARACTERISTICS (V_{CC} = 12 Vdc, T_A = 25°C, Circuit Of Figure 1 Unless Otherwise Noted.)

Characteristic	Pin No.	Min	Typ	Max	Unit
Supply Current	14	—	32	—	mAdc
Oscillator Amplitude	17	—	0.5	—	$V_{(p-p)}$
External Subcarrier Input (Oscillator Components Removed)	18	—	0.25	—	V_{RMS}
Subcarrier Input: Resistance	18	—	5.0	—	kΩ
Capacitance		—	2.0	—	pF
Modulation Angle (R−Y) to (B−Y)	—	85	90	95	Degrees
(R−Y) Angle Adjustment	19	—	0.25	—	Deg/µA
R, G, B Input For 100% Color Saturation	3, 4, 5	0.95	1.0	1.05	$V_{(p-p)}$
R, G, B Input: Resistance	3, 4, 5	—	10	—	kΩ
Capacitance		—	2.0		pF
Sync Threshold (See Figure 2e)	2	—	1.7	—	V
Sync Input Resistance (Input > 1.7 V)	2	—	10	—	kΩ
Chroma Output Level At 100% Saturation	13	—	1.0	—	$V_{(p-p)}$
Chroma Output Resistance	13	—	—	80	Ω
Chroma Input Level For 100% Saturation	10	—	0.7	—	$V_{(p-p)}$
Chroma Input: Resistance	10	—	10	—	kΩ
Capacitance		—	2.0	—	pF
Composite Output, 100% Saturation (See Figure 2d) — Sync	9	—	0.6	—	$V_{(p-p)}$
Luminance		—	1.4	—	
Chroma		—	1.7	—	
Burst		—	0.6	—	
Output Impedance (See Note 1)	9	—	—	100	Ω
Luminance Bandwidth (3 dB), Less Delay Line	9	—	8.0	—	MHz
Subcarrier Leakage In Output	9	—	—	40	$mV_{(p-p)}$

Note 1: Output impedance can be reduced to less than 10Ω by using a 150Ω output load from Pin 9 to ground. Power supply current will increase to about 60 mA.

Fig. 1 MC1377P data (Courtesy Motorola).

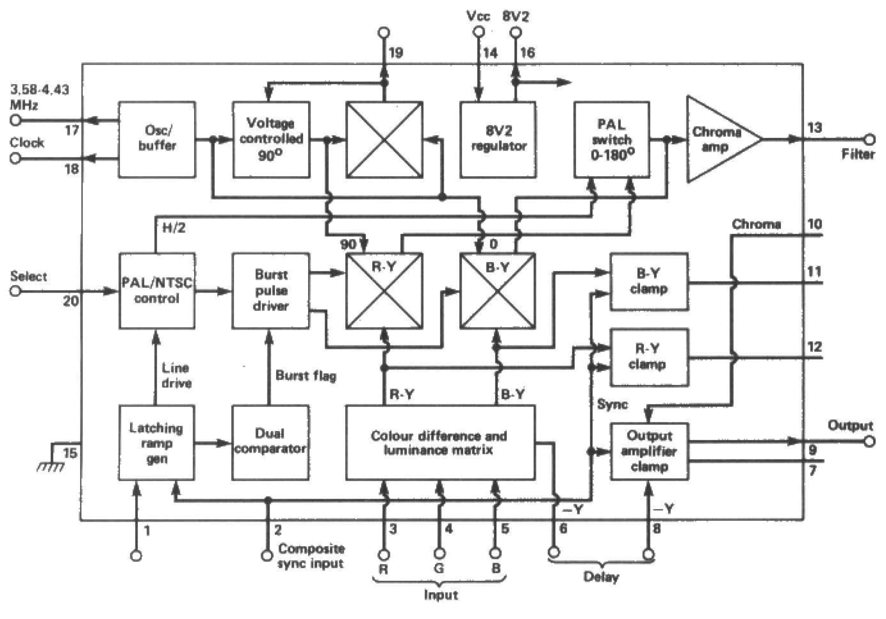


Fig. 2 Block diagram of the MC1377P encoder IC.

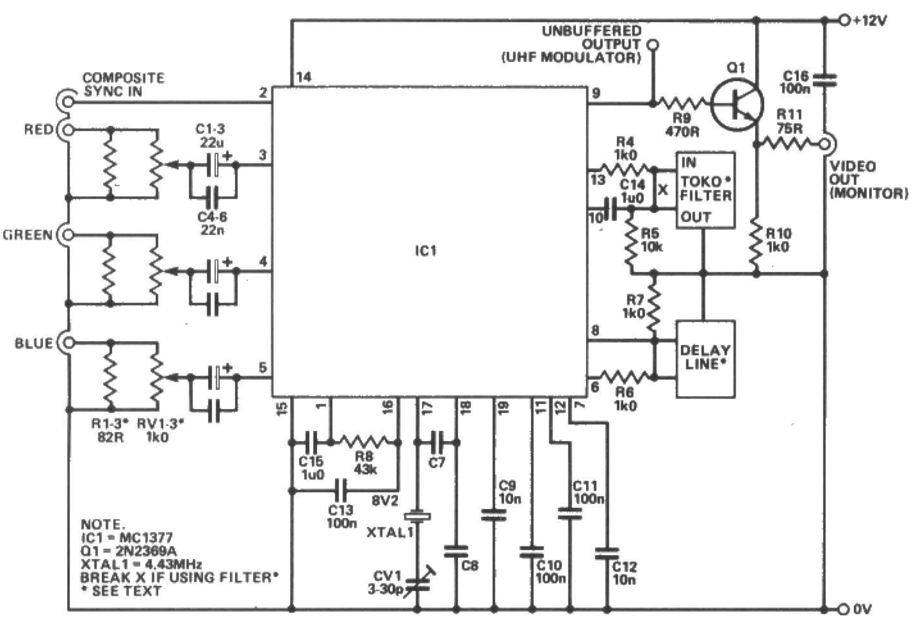


Fig. 3 Crcuit diagram of the converter.

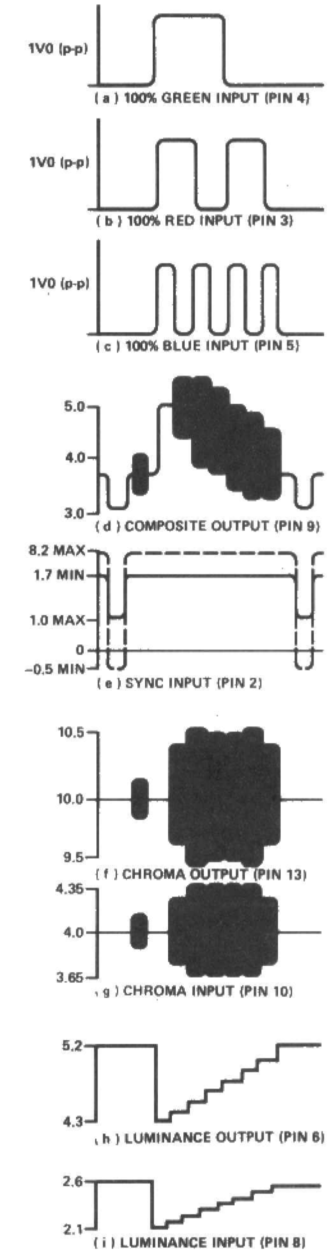


Fig. 4 The signals that should appear at the test points around the chip.

HOW IT WORKS

The incoming RGB inputs are terminated with resistors R1, R2 and R3 and potentiometers RV1, RV2 and RV3 (Fig. 3). These provide input impedances of approximately 75R. The presets should be adjusted to provide a maximum input of 1V p-p (for saturation) into the MC1377. If the inputs to the board cannot drive 75R (LSTTL, for example, can only provide a source current of 400μA) the 82R resistors should be removed and the pots replaced with 10k values. This will decrease the bandwidth of the system due to the filter formed by the potentiometer and the input capacitance of the MC1377. The inputs are AC coupled into the encoder — the large value of capacitor being required for the 50Hz field component.

The Colpitts oscillator for the colour burst is formed around pins 17 and 18. About 0.5V p-p should appear on pin 17 and 0.25 VRMS into pin 18 with the oscillator components removed.

The incoming composite sync signal (pin 2) should be negative going. The device will accept CMOS and TTL directly. The range of acceptable inputs is shown in Fig. 4. If it is necessary to AC couple the sync then a pull up to 8.2V is required (a regulated 8.2V is provided on pin 16).

From the composite sync input the MC1377 generates a ramp which it uses to provide the burst gate pulse. The slope of this ramp can be varied by a potentiometer on pin 1. However a preset value is usually sufficient (shown as 43k).

The chrominance filter should be fitted between pins 13 and 10. If the filter is not used, a compensatory potential divider should be fitted (both are shown in Fig. 3). We used a prealigned Toko bandpass filter centred on 4.43MHz. If the chroma filter *is* fitted, the delay through it (400ns) has to be compensated for by a luminance delay line between pins 6 and 8. This is shorted out if the filter is not fitted. The composite video output from the IC is buffered to provide a low impedance drive for a monitor or it can be applied directly to one of the common UHF modulators used in computers. Just follow the manufacturer's instructions for connecting this up.

modulator output to the chroma amplifier which drives the chroma bandpass filter if required. The output of the filter is fed together with the composite sync signal and a delayed version of the luminance signal to the output amplifier. The delay line in the luminance path compensates for the delay through the chroma filter.

It is possible to link out the chroma bandpass filter in which case the delay compensation is no longer required either. However the chip expects a 3dB loss through the filter and a resistor divider must be used instead to produce this.

Construction

With some care, no problems should be experienced. The circuit draws about 40mA from a 12V supply. The input potentiometers (RV1, RV2, RV3) should be set to provide 1V inputs from the source. If a scope is not available, they can be set up by viewing the picture on a monitor and obtaining good saturation of each of the inputs in turn. If necessary a small adjustment may be made to the R-Y phase delay. R8 can be replaced with a 50k pot and again adjustment made to set the correct hues on a monitor. A colour signal will be useful here, perhaps your computer can be programmed to generate one.

Should only 0.7V video outputs be available these must be amplified before applying them to the IC. A LM318N fast op-amp can be used (no compensation required) to provide the required gain at the bandwidth necessary. Take care to decouple close to the op-amp.

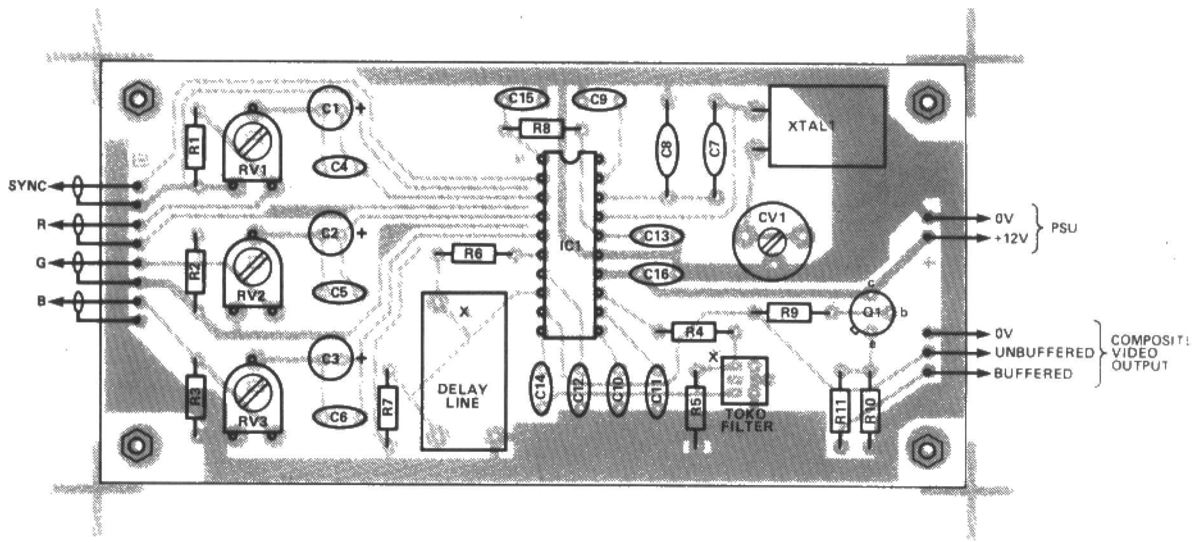


Fig. 5 Component overlay.

PARTS LIST

RESISTORS (All ¼W ±5%)

R1, 2, 3	82R
R4	1k0 (2k2 without filter)
R5	10k (only fitted when filter isn't)
R6, 7, 10	1k0
R8	43k
R9	470R
R11	75R
RV1, 2, 3	1k0

CAPACITORS

C1, 2, 3	22µ 16V radial electrolytic
C4, 5, 6	22n
C7, 8	22n
C7, 8	220p polystyrene
C9, 12	10n
C10, 11, 13, 16	100n
C14, 15	1n0
CV1	3-30p

SEMICONDUCTORS

IC1	MC1377P
Q1	2n2369A

MISCELLANEOUS

Chroma filter - Toko VUS1054; 400ns delay line. 3-pin 1" 1" x 4" (HLW); XTAL1 — colour burst frequency. 4.433619MHz, HC18U can; PCB; suitable connector.

BUYLINES

The MC1377P is available from Macro-Marketing (telephone: 06286-4422). The Toko filter and variable capacitor are available from Cirkit, order numbers 18-01054 and 06-36001 respectively The delay line — a TDK T9006 has been recommended — may prove more problematic and we suggest trying TV repair shops for a second-hand luminance delay line from a colour TV chassis — Fergusson TX9 or TX10, for example. Manor Supplies of West End Lane, London NW11 (01 794 8751) may be able to help. The 43k resistor may be obtained from Electromail or a 50k preset will do — or use a 33k and a 10k resistor in series.

ETI

MAINS CONTROLLER

Light provides the means to control your mains - safely!

From time to time, ETI has looked at ways to control mains powered equipment safely from logic circuits, with solutions becoming less complicated as better components became available. Of course, there's no particular problem in driving a triac from logic circuits if you don't mind having the entire circuit live, but this can lead to all kinds of hazards. Some kind of isolation is needed to keep the mains voltages separate from the low voltage circuitry.

Isolating pulse transformers used to be the answer to the problem, but these days there is a much simpler solution: opto-coupled triacs. Figure 1 shows the internal components of a typical opto-triac — the MOC3021. Instead of being turned on by a gate connection, the triac is triggered by light from the internal LED, and since there is no electrical connection between LED and triac, the low voltage side is completely isolated from mains voltages. The MOC3021 will stand at least 2,500V between the input and output sides of the circuit!

Because the MOC3021 can only switch currents up to about 50mA, it is almost always used in conjunction with a larger triac which can handle much higher currents. The triac used in this project is a TAG136D, which is suitable for currents of up to 4A.

Construction

The complete circuit for the project is shown in Fig. 2. and the component layout in Fig. 3. The box marked 'load' represents the device your want to control — a light, your hi-fi, an electric motor, or other mains powered equipment. The controller is connected between the live side of the mains and the equipment, just as if it were an ordinary switch.

When mounting the triac on its heatsink, first lay it on the board with the hole in its tab over the mounting hole in the PCB. You can then judge exactly where to bend the leads. Bend them at right angles to the body of the triac, then insert the triac leads temporarily into their holes, and check that the tab hole is aligned with the PCB hole. Take the triac off the board, smear the tab with a little heatsink compound, then bolt the triac to the heatsink and board *before* soldering the leads. This ensures that the triac tab lies flat against the heatsink for good thermal contact. Don't use the triac mounting bolt to fix the PCB to the chassis or case — there are other holes for this purpose. With many types of triac, including the one used in this project, the tag, and therefore the fixing bolt, will be live.

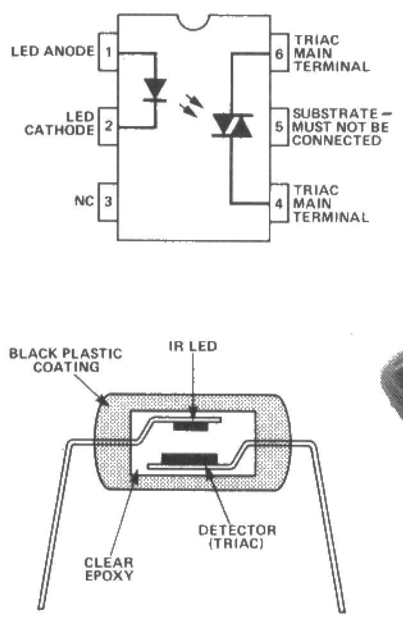
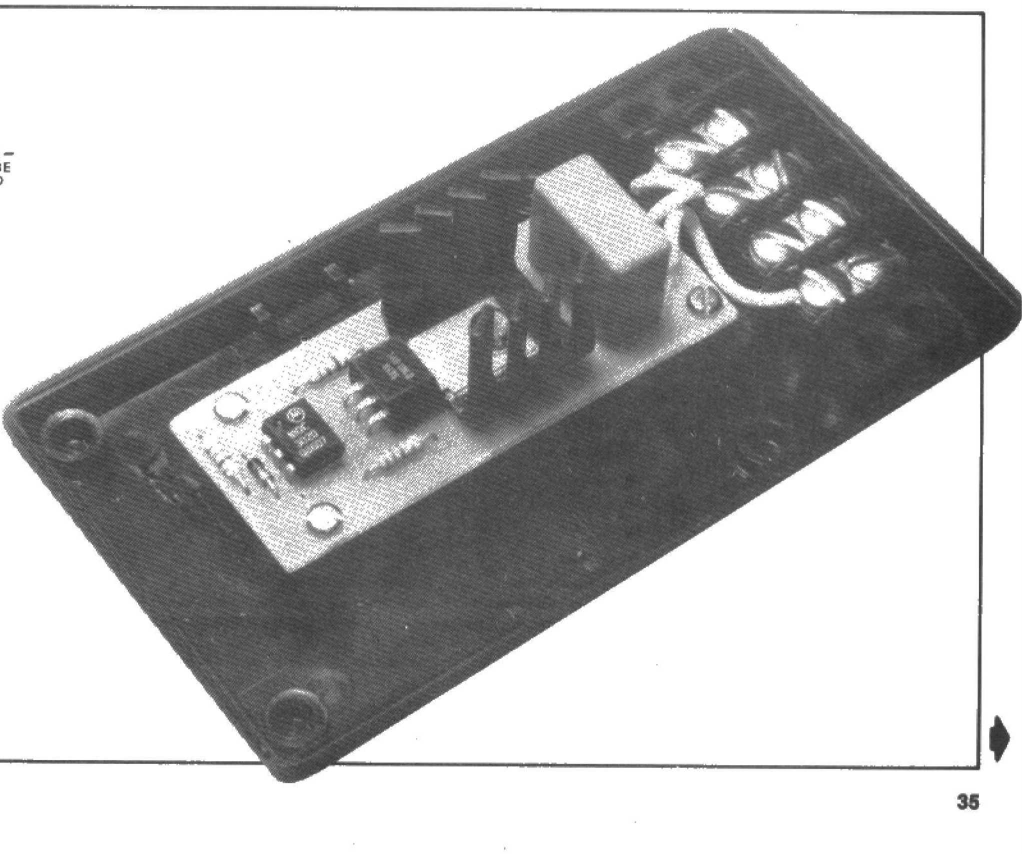


Fig. 1 Internal circuit of the MOC3021



Using the controller

The simplest way to switch equipment on and off is with a battery and switch, as shown in Fig. 4a. You may prefer running small and cheap low voltage wire rather than mains cable for remote switching.

Fig. 4b illustrates the way to drive the controller from TTL logic. The on-board resistor will limit the LED current to a suitable value for use with TTL, so the circuit is simply connected between the output of the logic IC and the +5V rail.

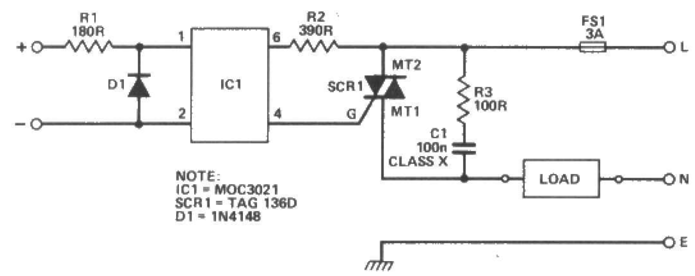


Fig. 2 The circuit of the mains controller

HOW IT WORKS

The control voltage is applied to IC1 via R1, which limits the current to about 17mA when the circuit is driven directly from a TTL IC. D1 protects IC1's internal LED from reverse voltages which could damage it, just in case the input is accidentally reversed. D1 will only be necessary if the circuit is used for experiment — if it is built permanently into a piece of equipment, this component can be omitted.

IC1 provides isolation between the low votage input and the mains switch. When sufficient current flows in the LED ('typically' 8mA, maximum 15mA), the internal triac will turn on. This, in turn, switches on the main triac SCR1.

R2 limits the surge current in IC1 and SCR1's gate. If the MOC3021's triac happens to be triggered when the mains voltage is at its peak, R2 must limit the current in both the IC and the gate circuit of the main triac to less than 1.3A, which is the maximum that either will stand without damage. As soon as SCR1 turns on, the voltage will drop almost to zero. The current surge will therefore be very brief (about 3μs), so a ¼W resistor is adequate.

R3 and C1 form a snubber network to prevent spurious re-triggering of the triac when it is used to switch inductive loads. If the circuit is used only for resistive loads, these components can be omitted — the extra board space could be used to accommodate a larger heatsink.

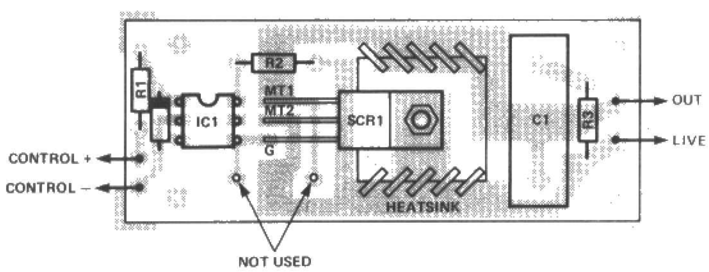


Fig. 3 Component layout of the mains controller.

PARTS LIST

RESISTORS		**SEMICONDUCTORS**	
R1	**180R**	**IC1**	**MOC3021**
R2	**390R**	**SCR1**	**TAG136D**
R3	**100R**	**D1**	**IN4148**
CAPACITORS		**MISCELLANEOUS**	
C1	**100n class X**	**PCB; heat sink; heat sink compound; mounting hardware; case (optional).**	

Figure 4c shows how you can control up to eight mains powered devices from the 'Interbeeb' and 'Interspec' computer interfaces, currently available from our Readers Services. This opens up all kinds of possibilities for household control systems — a sophisticated heating controller, for instance. Temperature measurements can be made via the A to D converters on the interface with suitable thermistors, or with an LM334 IC (Fig. 4d).

Interface with CMOS logic requires a means of stepping up the current available to drive the opto-triac's LED. Where only one or two mains controllers are used, the easiest method is to use a transistor, as shown in Fig. 4e. If you intend to drive several mains controllers, one of the many CMOS to high current ICs can be used (eg the ULN2001).

The maximum load that can be controlled with the project is about 500W, which is sufficient for most domestic appliances. This is limited by the amount of heat that can be dissipated, not the triac's current rating, which is why there was so much detail about mounting the triac. It is the most important part of the asembly. If the controller is to be used for loads close to maximum, the circuit must be in a well ventilated enclosure to allow air to flow freely around heatsink.

Triac And See

If you want to use the circuit with triacs other than the type specified, the PCB and heatsink will fit any T0202 or T0220 type with the leads in G-MT2-MT1 order. The substitute should have a gate sensitivity of 25mA or less in the 1+ and 111— triggering modes. The blocking voltage VDRM must be at least 400V. Also, check that the gate surge current rating is at least 1A for 3us. If not, the value of R2 must be increased to limit the surge current to a suitable value. As previously mentioned, there is no point in uprating the current capability unless you intend to use a much larger heatsink. Instead, the highest load capability will be achieved by choosing a triac with the lowest possible on-state voltage to reduce heat dissipation to a minimum.

A word of caution. Although the LED side of the circuit and

anything connected to it will be safe, the triac side of the circuit, most of the PCB tracks and the heatsink will be live. Don't attempt to test the circuit when it is connected to the mains. The triac will switch low voltages too, so you can test the circuit with the ouput of a 12V transformer and suitable load connected to the mains terminals. A 100ohm resistor can be connected in parallel with R2 to fire the triac at a lower voltage for test purposes, but don't forget to remove it before connecting the circuit to the mains. When you put the circuit in a case, make sure that the live parts cannot be touched, and that there is enough clearance between the live parts and any adjacent metalwork or low voltage wiring so that they cannot accidentally come into contact.

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BUYLINES

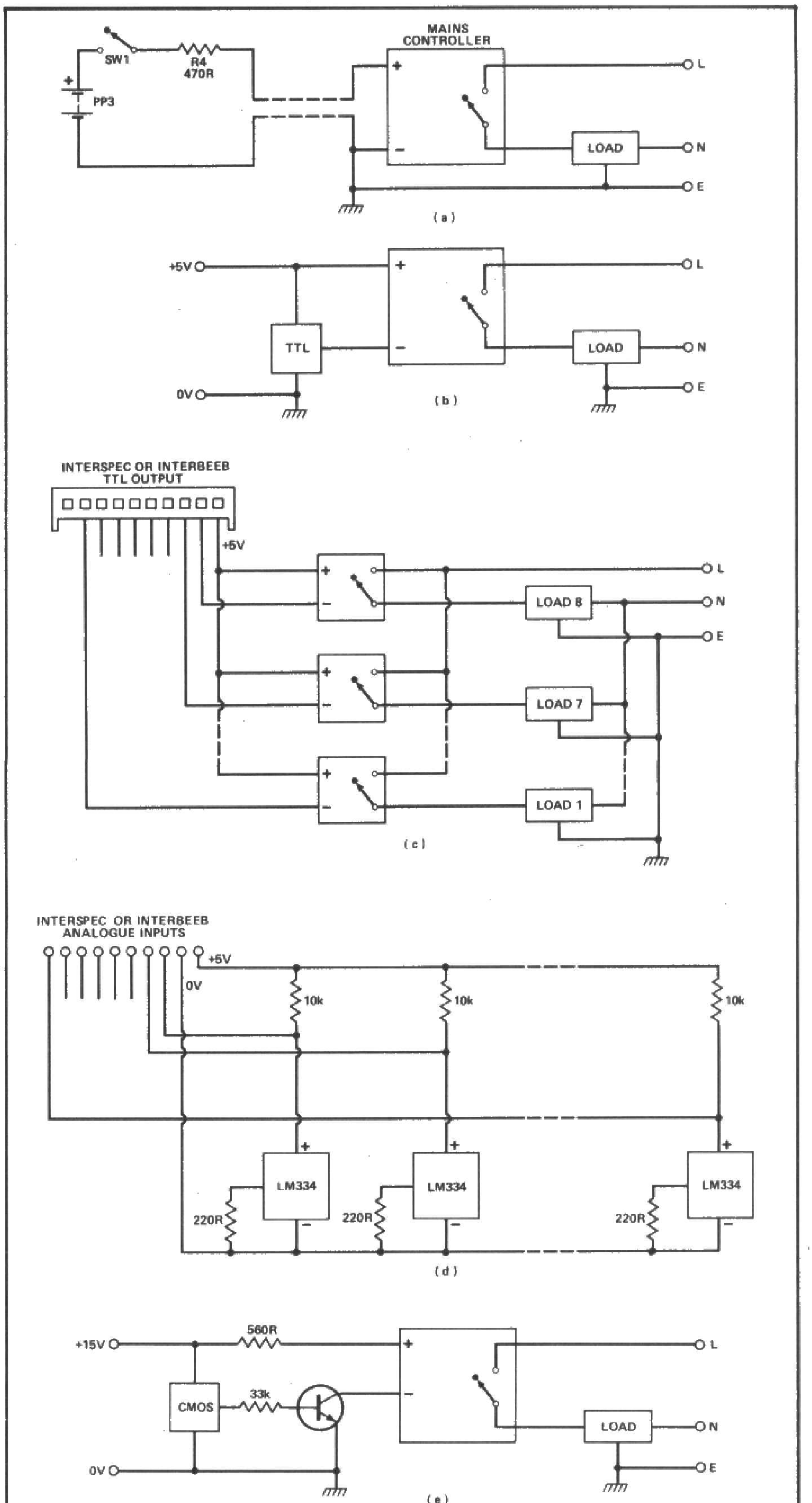
The MOC3021 opto triac is available from: STC Electronic Services, Edinburgh Way, Harlow, Essex. The order code is 271 82X, and the price £1.84 inclusive of VAT. STC can also supply the 100nF class X capacitor, stock no. 56454X, at 25p inclusive of VAT. As STC change their prices frequently (sometimes downwards!), it would be as well to 'phone them first to check. Their number is 0279 26777. There is no postage charge for orders below £5.

The TAG136D should not present any problems. It also goes by the name of Z0410DE — it's the same device; the manufacturers have recently changed their coding scheme. The text gives details for selecting suitable substitutes.

A suitable heatsink is type FL58N from Maplin Electronic Supplies Ltd., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Maplin can also supply a small syringe of heatsink compound, order no.H-QOA. The price of the heatsink is 45p, the compound costs 65p and postage is 50p for orders below £5.

A complete set of parts for the project is available from Specialist Semiconductors, Founders House, Redbrook, Monmouth, Gwent. The set includes PCB, heatsink and compound, and all components, and costs £6.30. An optional case is available at £1.35. Postage on any order is 60p.

The PCB will also be available separately from our PCB service in due course.



Note: with the component values shown, the output from the temperature sensors will give one count for each °C change in temperature. To keep the circuit simple, and to avoid having to cancel offset voltages, the sensors read 'back to front' — that is, a rise in temperature will cause a fall in the digital output of the A to D converters. These sensors can be trimmed by making the 220 ohm resistors variable.

Fig. 4 Some ways of using the mains controller.

SPECIAL PULL-OUT

TAKING CARE OF BUSINESS

In this final instalment of our pull-out guide to starting your own business, we look at the career of an electronics consultant and investigate the importance of the business plan. Good luck and good business.

THINKING IT THROUGH

Nigel Wilkinson argues that a business plan is both necessary and desirable — and may be the most important document you'll ever write or read.

Eureka! you've just had this great idea for a business venture no one ever though of. You dash along to the bank and what do they say? 'Go away and think it through.'

Don't they realise how much it's going to make for them as well as you?

Perhaps they do, but with an estimated 1,000 bankruptcies a month, no financial institution is going to give or loan you any money without evidence that your business has been well thought out and carefully researched and will work not just in your head but in reality. This is where the business plan comes in.

Your business proposition, no matter how small, will not begin to be considered without a plan. As well as showing the mechanics of the business, it shows your commitment, your professional approach and your understanding of what you are taking on. It will also help show you just what is involved in becoming self-employed. It is the catalyst which turns a business idea into a business reality.

What's In A Plan

So what should a plan include?

You should start with a *curriculum vitae*. This is a formal introduction stating who you are, any qualifications you have and, most importantly, your experience and knowledge of the business field you are entering.

This should be followed by a *business directory*. This should be as short and direct as possible. Try to answer the question, 'What exactly is your business?' Be precise, but avoid using too many technical words. Say, 'We hire out Public Address systems for pop groups and discos.' Do not say, 'PA hire for gigs.' Also describe how your business will have a different 'angle' from any competition and how it will succeed against them.

One of the key elements of any business plan is the *market description*. This can be divided into two main sections. An analysis of your market research and details of your marketing strategy. In the first part you should be able to describe the state of the market you are entering; how many potential customers there are, who and where they are; who your main competitors are, what they do well, and not so well, and what you have learned from them.

When detailing your marketing strategy, you must be able to show how you will price your product or service and what methods you may use. You should say what methods of advertising and promotion you will use, newspaper adverts, direct mail or exhibitions, for example and what they will cost if used on a regular basis. You must go into the sales methods you will employ — for example, *cold calling, market stalls or agents and what they cost. You should* also show your sales targets for the coming year.

At this stage you should detail any market testing you have carried out and give evidence of any firm orders you might have in the form of letters from customers and photocopies of your order book or receipts. These are the facts that will back your theory.

To complete the descriptive part of the business plan, you should add sections on; details of your *premises;* your *future plans* for the business; a list of *outstanding* needs, that is what exactly you need money for and details of any *other sources of finance.*

The Functions of Structures

If you are not a sole trader, it is a good idea at this point to detail the structure of your company co-op or partnership and include any relevant documents.

A business plan is not just a description of what you will do. It needs hard figures to back it up.

You should also have sections devoted to a breakdown of your *personal budget*, indicating how much you need to live on, and your *business overheads*, listing your fixed overheads for each week. Using these to work out your hourly labour rate (how much you will pay in wages or salaries per hour), you should give at least two examples of *costings*, or how much you need to charge for your product or service and how this is worked out. Costings can differ for any number of reasons. For examples, one set could refer to a situation in which you employ two people and one in which you work alone. In any case, the basics of each costing must be explicit.

Last, but not least, comes the *cash flow*. If you have worked through the rest of your business plan thoroughly this should hold few problems. It is simply a financial forecast of how your business will run over a period of time — usually one year — based on all your information.

Lasting And First Impressions

As with all aspects of a new business, first impressions count for a lot. Give some though to the presentation of your proposal. Always type it out on headed notepaper. It is also a good idea to include sketches or photographs of your product/service, but don't make the document so bulky it is unreadable.

If you want further help with your plan — and it is a good idea to check it over with someone, anyway — contact your local Enterprise Agency, Small Firms Advisory Service or find out details of local small business training schemes, most of which are free. Details of these are available from your local Library or Job Centre — and from our Useful Addresses section.

Don't forget that the leading banks all publish material to help and advise new businesses. The National Westminster and Midland banks, in particular, produce excellent booklets. The Midland have a particularly useful one on the business plan in worksheet form. These should be available over the counter.

Finally, remember that the most important reason to write a business plan is to help you sort out your ideas and thoughts. It will show you the commitment required and problems you are taking on. It should show you whether the business will work or not. Once you are sure of your business idea you will be in a stronger position to convince potential investors or backers. Now do you see why you need to think it through?

GOING IT ALONE

Marcus Smith talks to a consultant engineer about electronics consultancy, how to run and not to run a company and the pros and cons of working in a team.

After two years as his own boss, David Roberts is in a position to appreciate the pros and cons of independence. A consultant designer of PA and lighting control circuitry, he divides his time 'almost equally' between customers, and his office in west London. He is almost the textbook industry boffin, lanky, smart anorak over his business suit, expensive brief-case, modest beard, Reebok trainers. He stands out instantly as the Consultant Engineer.

Personally, Roberts does what he always wanted to do: he makes things work. Professionally he knows that he is at the crossroads.

A consultant can make a comfortable living for an honest day's work, but Roberts wants to aim for the higher rewards of the successful entrepreneur. His ideal is to keep both executive responsiblity and close links with practical engineering.

He knows that the ideal is hard to realise, because he has tried it before.

After six years in a company formed with two college friends, he resigned, a round peg in a square hole, putting himself 'almost back to square one, say square one and a half.'

'We were all rather unprofessional, and the unprofessionalism won out under pressure ...'

What was your original career plan when you left college?

'I wanted to work for myself even when I was at school. I had health problems which meant that keeping fixed hours was not as productive as flexible ones. At college I made two good friends, one who wanted his own company, and a brilliant chap who just wanted to work with microprocessors. We agreed in principle that we would start a company as soon as we had the resources.

Did you go solo soon after you left university?

No. I worked in Essex for two years, designing audio circuits, and then with a test equipment company on flexi-time. This suited me much better — if I got tired, I could leave and make up the time the next day. My health bothered me less, and I began to look around for bits of freelance work.

About this time, friend number one felt that he wasn't getting any further in his job, and we talked about the company again. We were both earning well and living cheaply in east London, our wives were ready to support us, and I had been offered two freelance projects by people I knew before. We decided on a limited company to have some individual protection in the event of financial failure.

A limited company protects its executives from massive personal debts if the company goes into liquidation for any reason ...

Yes and no. If a company has a lot of credit, and goes into liquidation, the directors aren't personally bankrupted. But if they have personal securities against loans, or have put money into the company, they lose that money.

You might lose your house if you had secured a loan on it which you couldn't cover. With a new company with no capital value, the only way to raise money, apart from venture capital which splits control of the company, is by personal borrowing.

What did you actually start with?

I had been offered some lighting control by one company and industrial video add-ons by another one. I was the first to leave my job and start work alone. The office was in my spare bedroom, and we had a light box and a small work bench for prototyping. Six months later one of my partners joined me.

Everything didn't go too smoothly at first. We were all rather unprofessional, and the unprofessionalism won out under pressure. We lost a great deal of customer confidence. Happily, we managed to reverse the trend when we realised what was happening.

What do you mean by unprofessional?

We fell into the trap of undercharging, and then rushing the job. I think we should have aimed for the quality, and then said afterwards, well, we miscalculated the price, and in future it will have to be more. There was a tendency to quote the lowest price that was plausible, then find it took twice as long as we had estimated, and to try and cut corners.

With microprocessors, it sometimes took us four times as long as we had estimated. I was in the position of saying, it's got to take longer, but the others took a different view. If we tried to be coldly realistic about estimates the customers were unhappy about the cost.

You are talking about companies who were inexperienced, not simply trying to get a cut price job?

Oh, indeed, it was a mutual education process. They had no idea what it involved and we were always a bit too optimistic.

'At one stage I was lending the company about £6,000 just to pay off creditors ..'

Where were you working at this time?

Still in my back bedroom, and my partner had a work-station in his home a few miles away. We decided to move before we set up a permanent office, so we went west till we found hosues we could afford. Then it took another six months to find an office in the town, with a small workshop.

We had just moved when one of our customers had its funding called in by the NRDC (National Research and Development council). They developed a machine and then discovered that their potential customers wanted something different. They got a further grant from the NRDC, but a few weeks after that, just as a few machines were being sold, the

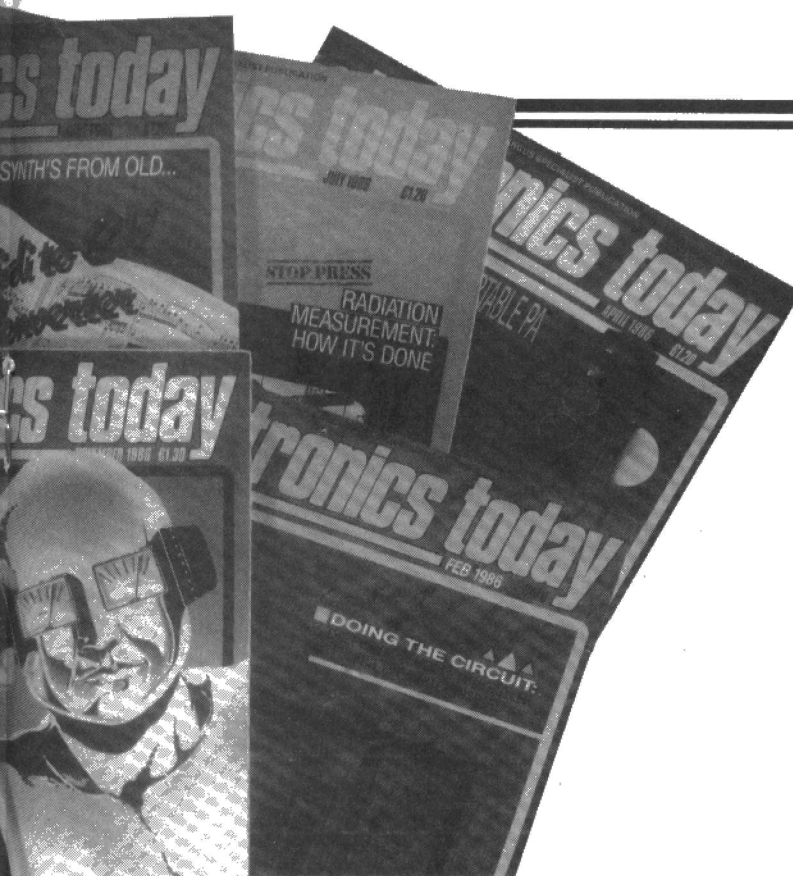
INDEX 1986

1986 is (almost) over and it's time to take stock of all the great articles ETI has brought you in the last 12 months. Regular items such as News Digest, Read/Write, Open Channel, Playback, etc, are not included, but all major features and project articles are listed below (cross-referenced two or three times in some cases to make them as easy to find as possible) along with Tech Tips, Circuit Solutions and Reviews. We have also listed all corrections and updates relating to major articles.

Projects

Tech Tips & Circuit Solutions

Features



INDEX 1986

Reviews

If you wish to order copies of any of the articles listed in this index, you can obtain backnumbers of the relevant issues from Infonet Ltd, Times House, 179 The Marlowes, Hemel Hempstead, Hertfordshire HP1 1BB, tel 0442-47432. The cost will be the present cover price of the magazine plus 50p to cover postage, etc. If on applying you find that Infonet have sold out of the issue you require, you can obtain photocopies of individual articles direct from us. The address is the ETI Photocopy Service, 1 Golden Square, London W1R 3AB. The cost is £1.50 per article including return postage to you, but note that, where an article appeared in several parts over a number of months, each part will be charged as one complete article. Cheques and Postal Orders for both backnumbers and photocopies should be made payable to ASP Ltd.

ETI

NRDC asked for repayment and the whole thing folded.

All we could find out was that the NRDC had pulled out for 'valid commercial reasons'. It happened just at the moment when we least expected it.

We lost two months turnover and hit a very embarrassing dead patch when we had planned work. To add insult to injury, we had to pay VAT on the money that hadn't been paid! I believe there is now a way of reclaiming VAT on bad debts, but there wasn't then.

We were also designing a microprocessor lighting controller, a very complex project, on a very low quotation. By dint of one of the partners working through the night, round the clock, round the week, round the month, it was completed to some sort of a standard in time to save the company from insolvency.

At one stage I was lending the company about £6,000 just to pay off creditors. To do that I took a high percentage mortgage which was costing way over the odds. It was a year before I could change that, so I had to borrow from my parents. The loan money was eventually paid back, but I ended up £800 out of pocket just from the mortgage.

'There was a tendency to quote the lowest price plausible, then find it took twice as long as we had estimated, and to try and cut corners — with microprocessors, it sometimes took us four times as long as we had estimated ...'

You mentioned that the company was working on a big microprocessor control project, and that one of the partners was working very long hours. Why one? Were you specialising?

No. It was very much this chap's style to set a tight deadline and then work round the clock to meet it. Some people thrive on that, and in this one case it was necessary, but the trouble was that the work was being planned for this kind of schedule. If there was an unplanned problem, and there were usually several, then the work was completed late.

This caused a lot of stress. On one occasion my partners told me that I caused a week's delay by a half day spent finding a pin connection error on a complicated PCB. Later a misprint was found in the data book, but I was in some mysterious way still held responsible.

You said that your differences of opinion had something to do with working style. When did this start?

It did seem to me that our personalities and working styles clashed. There were serious disagreements which ended in an extremely acrimonious split, but it started with this software project, which was also the time when the third partner joined the company.

I think he, quite unintentionally, destabilised the company. He is a very good engineer, better than either of us by far, and I suppose because the emphasis was on programming at the time, they came to see more eye to eye and to find faults in my way of working.

When we started, we were writing in hexadecimal. It was a new area to both of us, and I was very unhappy about the amount of work we had to do in a short time. My partner seemed a lot more confident, and so I let him take over the planning stages while I got on with other work. He wasn't very interested in circuitry, as I was, and preferred programming.

If we had been working together longer, perhaps I would have realised that he was being confident to convince himself that he could do the job, and he would have realised that my anxiety needed practical reassurance that he knew what we were taking on, not just a show of bravado.

'I want to design good work, and make a reasonable living — I would be very cautious before considering another partner ...'

This meant that we were often working at cross purposes. If either of us had understood what was happening, we could have solved it at the stage, or broken up in relative peace.

When he took over the project we bought an Apple II computer. He installed it at his home — in the bedroom — and sat up night after night with it. I can't help feeling, now, that he was making a statement about what all this meant to him.

In one software consultancy we knew of, the only programmer who wasn't divorced over a four year period was the freelance who knocked off around the same time every evening. Divorce is endemic among programmers and company directors. It hasn't happened to me yet, I'm glad to say.

There was a fundamental difference between us. They would do a 36 hour stint every so often, while I couldn't manage more than 15 hours in one go. My work deteriorates or I damage something expensive. I couldn't take the pace they were setting on their terms, and my commitment and usefulness were devalued.

In what way did the disagreements become acrimonious?

I require notice of this question. I think you have a situation of positive feedback, where, once a disagreement has started, it is easier for it to get worse. And with three people — it seems very obvious, looking back on it — there is a severe risk of a two-to-one split occurring, whereas if you've got two, there's nothing to do but discuss things until you reach some kind of agreement.

It got to the stage where it seemed to me that any work I did would be torn to pieces and scrapped ... I was virtually told at one stage, by my partner's assistant, who wasn't an engineer, that it was a waste of the firm's resources for me to make a prototype board, and I should get it right first time!

It was funny, but I eventually left because one of my partners suddenly decided to side with me against a plan put forward by the other one. The other chap resigned on the spot. He and his assistant knew more about the administration of the company than either of us, and knew that the company would effectively collapse if he left, so I offered to resign instead, and that was that.

I decided to set up by myself as I had origianlly planned, but the obvious conclusion was that I would end up working for the same customers, who I had right at the start. The others wanted those customers to ensure the company's viability.

The notion that these quite large companies had more work than either of us could tackle never seemed to arise. Paranoia just took over. There were threats of

violence, among other things, because they were worried that I might take business which they would otherwise have had.

It sounds as though the company wanted to stop you from working for people you had been working for for a long time. Were they able to do this?

Legally they had no right, but I had joint standing liability for the company's debts, and they refused to release me unless I gave them an agreement. There was also money which I had lent, or was owed in salary.

I suggested that I should hold, say, ten per cent of the shares to prove that I had an interest in the company — there were family ties as well — but they told me that if I refused to sell them my shares for the face value, they would make sure that the company never had any more than the face value. They could in fact have done this, by winding down the company, transferring the business and assets to a parallel company, and winding up the original company in good order but with no profits to the shareholders. I could have lost the value of the shares completely.

They wanted me to sign an agreement that I wouldn't work for any of their customers for two years, and in return they would give me what I was owed. Effectively, they told me that my contribution to the company was of no signficant value, but on the other hand I would threaten them as a competitor. In the end I was released without an agreement.

The whole business was a mass of postures and misunderstandings. I got most of the money which a year earlier they said was owed to me. There were some downward adjustments, which they said applied to everybody, and I simply went along. In this situation, the pressure is great and you don't always see things clearly.

When I left my confidence was badly dented, and I was bitter about the way they had tried to stop me from working in my field. I owed a lot to friends who knew something about both sides and were able to give me as well as the others some support.

I want to design good work, and make a reasonable living, I would be very cautious before considering another partner, but I know now that politics can crop up wherever people are trying to do a job, and you have to try to maintain people's confidence in themselves and in you. I would always make an effort not to do to other people what was done *to me*.

The worst thing, apart from the terrible lack of trust around the breakup, was that I lost my two best friends. At first I never wanted to see either of them again, but when the mistrust died down they made an effort to be friendly and my wife helped to smooth things over. Now we are all doing reasonably well, and I can look forward again to the next stage.

I can manage my own time again, and I have gained back the two stone I lost in my last year at the company. I wish I had only gained back part of it! **ETI**

USEFUL ADDRESSES

GOVERNMENT AND INDUSTRIAL ORGANISATIONS

British Safety Council

Will help with safety at work information.
62-64 Chancellors Road
London W6 9RS
(01 740 1231)

British Standards Institution

Have detailed information on design criteria, which will be important if you wish to produce quality products or to find out what standards your competitors work to.
2 Park Street
London W1A 2BS
(01 629 9000)

Institute Of Science Information

132 High Street
Uxbridge
Middlesex UB8 1DP
(0895 30085)

Institute Of Production Control

National Westminster House
Wood Street
Stratford upon Avon
Warwicks CV37 6JS
(0789 205266)

Manufacturing Advisory Service

PERA (Production Engineering Research Association)
Melton Mowbray
Leicestershire LE13 0PB
(0664 64133)

Micro-Electronics Industry Support Programme (MISP)

Electronics Application Division
Room 514
29 Bressenden Place
London SW1E 5DT
(01 213 3982)

Central Statistical Office

Great George Street
London SW1Q 3AQ
(01 233 3000)

Department Of Energy

Thames House
South Millbank
London SW1P 4QJ
(01 211 3000)

Department Of The Environment

2 Marsham Street
London SW1P 3EB
(01 212 3434)

Department Of Industry

Ashdown House
123 Victoria Street
London SW1E 6RB
(01 212 7676)

British Overseas Trade Board

Exporters and would-be exporters should approach them.
South East Regional Office
Ebury Bridge House
Ebury Bridge Road
London SW1W 8QD
(01 730 9678)

Confederation Of British Industry

National organisation of major employers who may help with research.
Centre Point
103 New Oxford Street
London WC1A 1DU
(01 379 7400)

Job Creation Ltd

17/18 Old Bond Street
London W1X 3DA
(01 409 2229)

Companies' Registration Office

Companies House
Crown Way
Maindy
Cardiff CF4 3UZ
(0222 388 588)
LONDON OFFICE:-
Companies House
55-71 City Road
London EC1Y 1BB
(01 253 9393)

The Institute Of Small Business

11 Blomfield Street
London EC2M 7AY
(01 638 4937)

National Consumer Council

18 Queen Anne's Gate
London SW1H 9AA
(01 222 9501)

National Economic Development Council

21-14 Millbank Tower
Millbank
London SW1 4QX
(01 211 3000)

Office Of Population Censuses And Surveys

St. Catherine's House
10 Kingsway
London WC2B 6JP
(01 242 0262)

HM Customs And Excise General Enquiry Office

For VAT enquiries and import/export regulations
Kings Beam House
Mark Lane
London EC3R 7HE
(01 626 1515)

Health And Safety Commission

Would-be employers should contact, to find out their legal requirements.
Regina House
259-269 Old Marylebone Road
London NW1 5RR
(01 723 1262)

Chambers Of Industry And Commerce

Local Chambers of Commerce will give information and assistance to new businesses.
Sovereign House
212A Shaftesbury Avenue
London WC2H 8EW
(01 240 5831)

Compiled by C.M. Herman

THE BETTER FLANGER

Invent a better flanger, they say, and the world will beat a pathway to your door. Well, Ian Coughlan has, so come on world!

As if to reinforce the flanger's popularity, they appear with seemingly monotonous regularity as projects in electronics magazines — even ETI has published a few in its time. So why publish yet another?

There would be little point if each design was just a rehash of earlier ones and not an improvement on its predecessors. This design seeks to provide a level of performance and sophistication at least a *little* bit better than previous designs, and, it is hoped, approaching that of commercially available flangers.

How It's Done

Flanging is closely related to the chorus effect. This design is even based on the chorus unit that appeared in ETI, November 1985, using many of the same components, and a modified version of the chorus PCB. This may sound like just the sort of rehash mentioned above, but the original chorus unit was an improvement on earlier designs and the flanger improves further on noise performance and frequency response.

Figure 1 shows the block diagram of the chorus (a), and the flanger (b). Note how similar they are.

The classic chorus effect is produced by delaying a portion of the input signal, varying this delay, and mixing delayed and undelayed signals at the output. These two signals will interact, sometimes adding together, sometimes cancelling out, producing peaks and troughs in the frequency response. As the delay-time is slowly varied, so these peaks and troughs will move up and down the audio spectrum. The effect is of subsidiary instruments or voices almost but not quite exactly mimicking the original — hence the name 'chorus'.

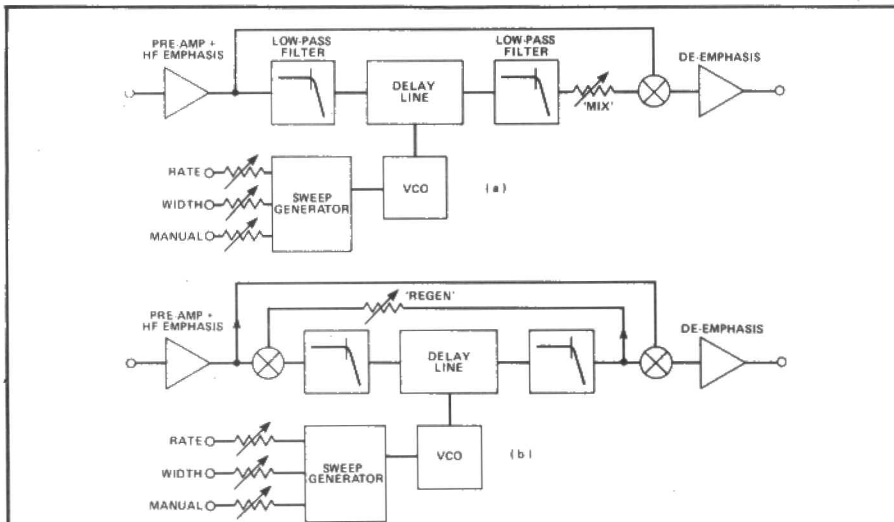


Fig. 1 Block diagrams of (a) the chorus unit and (b) the flanger.

The delay-time of the chorus is in the range 7 to 20ms. That of the flanger (similarly varied by a sweep generator) is shorter, in the range 1 to 13ms. This is one of the two major differences between the two effects.

The other difference is the addition of a regeneration control, by means of which part of the delayed signal is sent back round to be re-delayed. This would be a bit like reverberation if the delay-time was not so short. In fact, it is regeneration that gives the flanger its characteristic metallic sound.

Chip Is Down

The device at the heart of the flanger is a Bucket Brigade Delay-line (BBD), a TDA1022 IC which has 512 stages, or buckets. The principles of the BBD are dealt with at some length in the chorus unit project, ETI, November 1985, page 49.

The BBD device used in the chorus — a TDA1097 — cannot be used in the flanger. For a delay of between 1 and 13ms, the 1536 stages or buckets of a TDA1097 would require a clock frequency in the range 59kHz to 768kHz (since delay time equals number of 'buckets' divided by twice the clock frequency). The TDA1097 is only specified for clock frequencies up to 100kHz.

The TDA1022, however, has only 512 stages, and requires clock frequencies in the range 19.69kHz to 256kHz, well below the device's maximum of 500kHz.

Alias Hiss And Tones

A BBD line is essentially a sampling device and the clock signal will interfere with the audio signal. It will inevitably find its way to the output, but at a much lower amplitude than the audio signal and at 19.69kHz minimum. In other words, it will be barely audible.

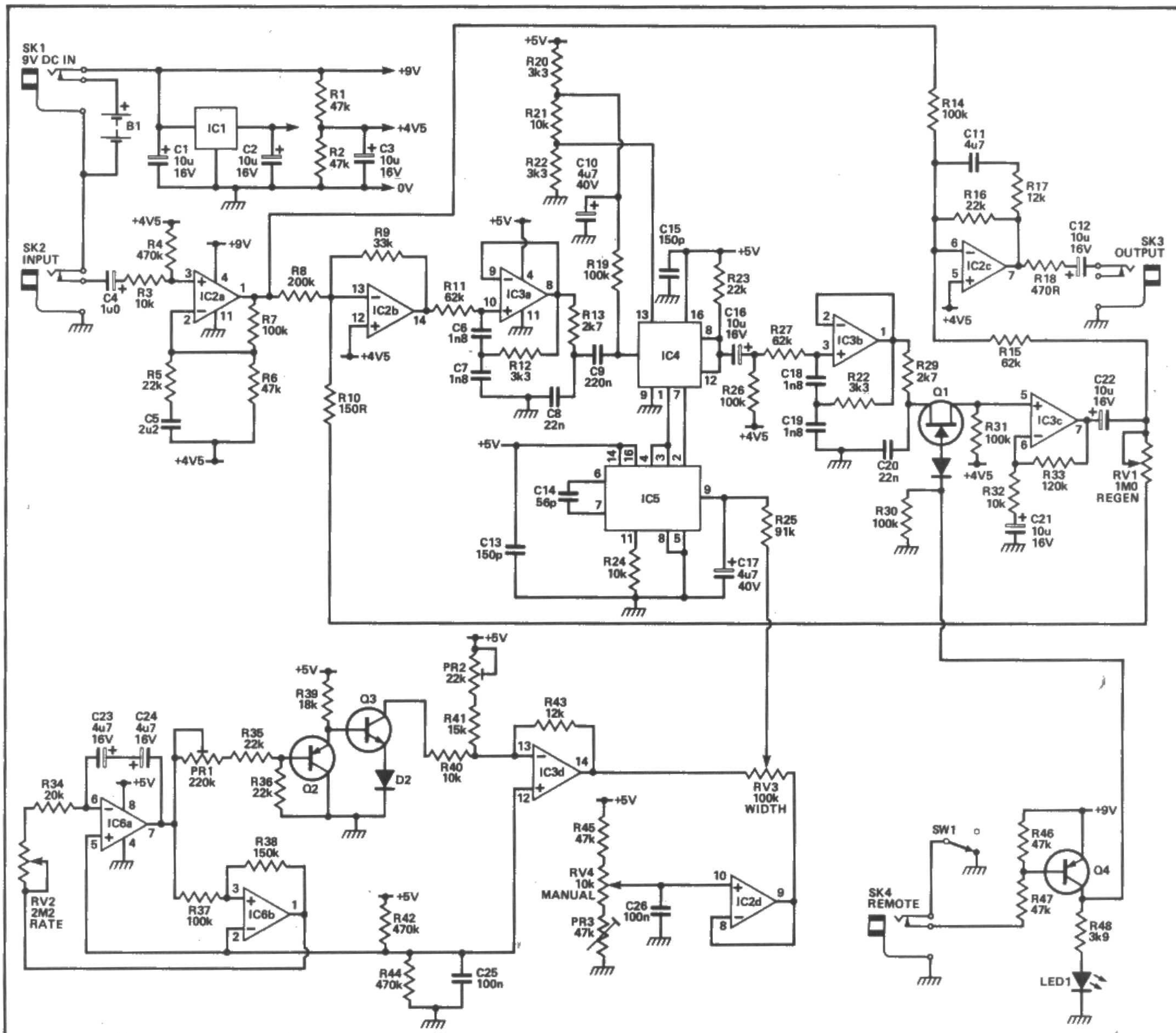


Fig. 2 Circuit diagram of the flanger.

However, as the harmonic or noise frequency components of the input signal approach half the clock frequency, the lower sideband of the clock frequency will become audible.

If frequency components (noise, signal or harmonics) are present in the input to the BBD line, they will mix with the clock signal to produce sum and difference components. The sum signals will be too high in frequency to be audible, but the difference signals may be well within the AF range.

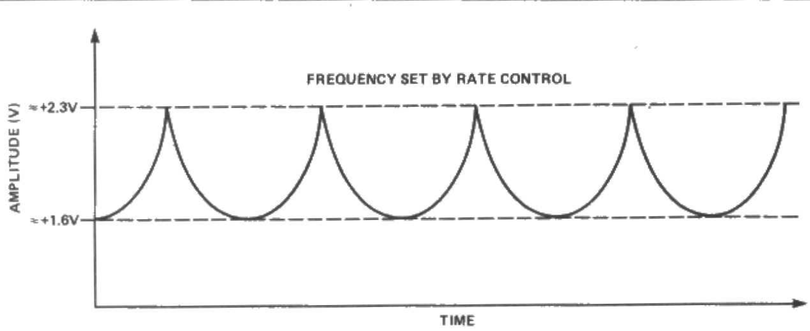


Fig. 3 Sweep generator output (IC3–14)

The circuit has a low-pass filter after the BBD line with a cut-off frequency of 6.2kHz and a slope of –20dB/octave. On its own, this filter would get rid of most of the difference signals — but the design has the added luxury of a similar low-pass filter *before* the BBD line.

Since input signals to the BBD drop off rapidly above the filter's cut-off frequency, difference signals below 13kHz also drop off rapidly. This reduces the amount of work the second low-pass filter has to do.

A cut-off of 6.2kHz may seem very low, but flanging — like chorus — becomes inaudible above this sort of frequency. In any event, only the delayed portion of the final output is affected: the undelayed signal is not filtered.

HOW IT WORKS

IC2a (Fig. 2) is connected as a high-impedance input buffer, and R5 and C5 provide high-frequency pre-emphasis, or boost, to the input signal. Part of this signal goes to the output stage and part goes to IC2b, which has a gain of about −15dB, and then through a low-pass filter built around IC3a.

This filter prevents high frequency components from reaching the BBD Line, IC4, where they may otherwise interfere with the clock signal, producing aliasing effects.

IC4 requires two bias voltages — provided by the divider chain R20, R21, and R22 — and two anti-phase clock signals — supplied by IC5, which is a 4046 phase-locked loop used here as a voltage controlled oscillator (VCO).

IC4 is specified for a supply voltage of no less than 10V. Because this is a battery-powered unit, and the supply to IC4 must be the same as that to IC5 (which has to be regulated), so 5V is all these two ICs get. The BBD device will still function, but the performance will suffer, and in particular, the attenuation from its input to output will be very much higher at this reduced supply voltage.

IC3b is connected as another low-pass filter, and gets rid of most of the clock frequency and high-frequency noise from the output of the delay line. Q1, a field-effect transistor, functions as a simple switch to gate the signal through to the next stage, depending on whether or not the effect is selected.

The next stage is an amplifier based on IC3c, with enough gain to compensate for the attenuation of the delay-line. The output from IC3c goes to the output stage, IC2c, and also back to IC2b via the regeneration control.

The RC network (R17 and C11) across the feedback resistor (R16) of IC2c will reduce the high-frequency response of this stage, but remember that the signal received HF pre-emphasis at the input stage, so the overall response is flat. This de-emphasis on the output stage also serves to get rid of a little more of the noise generated by the BBD line.

The sweep generator is built around IC6, IC3d, and IC2d. IC6a is an integrator, and IC6b is a Schmitt. If the voltage of IC6 pin 7 is of a sufficiently high level, pin 1 will also be high. This will cause pin 7 to ramp downwards at a rate determined by R34, C23, C24, and the rate control. When the voltage is low enough, IC6b will switch, sending its output low and causing pin 7 to ramp upwards, repeating the cycle.

The output from IC6a pin 7 is a triangular waveform, and is not much use for driving the VCO, which in turn determines the delay-time. As the triangular waveform reaches its lowest point, so the delay-time is at its longest, and the rate-of-change of the delay-time is high enough to cause a change of pitch in the audio signal passing through the delay line, resulting in 'whooping' effects.

The solution is to slow down the rate-of-change as the delay time approaches the 13ms end of its range. This is achieved by utilising the fact that bipolar transistors have a very non-linear switch-on characteristic at low levels of base current. This characteristic is used to turn the linear ramp output of IC6 into something approaching that shown in Fig. 3.

At the 2ms end of the delay time range, the rate-of-change is high but inaudible. At the other end, the rate-of-change is much lower. RV3 and RV4 are used to adjust the shape of the waveform.

This modified ramp signal is applied to one end of the width control, and at the other is a DC voltage, set by the position of RV4, the manual control. With the width control fully clockwise, the VCO gets its control voltage entirely from the sweep generator, so the delay-time is swept across its range. Turn the width control fully anti-clockwise, and the VCO frequency is set solely by the manual control. Thus the width control provides the option of a fully swept delay-time, a fully manual delay-time, or anything in between.

The effect is selected by the footswitch, SW1 or by a remote switch connected to the REM socket.

All the op-amps are supplied with +9V, except IC6, which gets +5V. The BBD line and its clock generator are also supplied with +5V from IC1, a 78L05 voltage regulator. Some parts of the circuit require half the battery voltage, and others require +2.5V. These voltages are provided by potential dividers.

The bulk of the energy in most music is contained in the low frequencies, so a little bit of high-frequency pre-emphasis is added to the flanger's input signal. This gently lifts the top-end of the input signal above the noise generated by the BBD line, under which it may otherwise get lost. De-emphasis has a further benefit in that it also filters out a little more of the noise introduced by the BBD line.

The delay time of the flanger is, of course, completely adjustable within the range 1 to 13ms. Rate, width, and manual controls allow a wide range of effects to be obtained.

With the width control at a maximum (fully clockwise), the delay time will sweep from maximum to minimum, at a speed determined by the position of the rate control. As the width control is turned anti-clockwise, so the width of the sweep is reduced, until it reaches zero sweep. At this point the delay time is set by the manual control and the rate control will have no effect.

The regeneration control lets the user determine how much of the signal will go back into the BBD line to be re-delayed. With the regeneration control fully anti-clockwise, the flanger will sound something like a chorus, not surprisingly, perhaps, given the similarity of the two circuits. With the regeneration control at a maximum (fully clockwise), the flanger produces an intense, metallic sound.

Construction

Begin by fitting the four jack-sockets and the wire link to the PCB. Sockets can be used for IC4, IC5, and IC6, but not for IC2 and IC3, since height is restricted at the end of the PCB when the unit is assembled in its case. The jack-sockets must be the recommended type or they will not fit the holes on the PCB.

Next, fit resistors, capacitors, and presets. Note that most of the capacitors at the same end of the board as the sockets are mounted flat, again because of restricted height.

Continue assembly by soldering lengths of insulated connecting wire between the points shown on the PCB overlay diagram, and connect the four potentiometers and the LED. Next, wire-up the battery connector, and fix the two battery guide pillars. The switch may be fitted temporarily for testing the PCB, but will have to be removed before the board can be assembled into the case. Alternatively, use a piece of insulated wire.

The PCB can now be tested. An oscilloscope will be necessary for accurate setting-up of the flanger.

With a battery connected, press the switch and check the LED lights. Connect the scope to IC5 pin 2, and check that a square wave signal is present, with an amplitude of about 5V peak-to-peak. With the width and manual controls fully anti-clockwise, adjust PR3 until the freqency of the square wave is about 20kHz. Turn the manual control fully clockwise and check that the frequency rises to about 250kHz. If either of these frequencies is outside the range of adjustment of PR3, try altering the value of R45. A frequency counter could be used for accurate setting of the limits 19.69 kHz and 256 kHz.

Next, connect the scope to IC6 pin 7, and check that a triangular waveform is present, with an amplitude of about 2V peak-to-

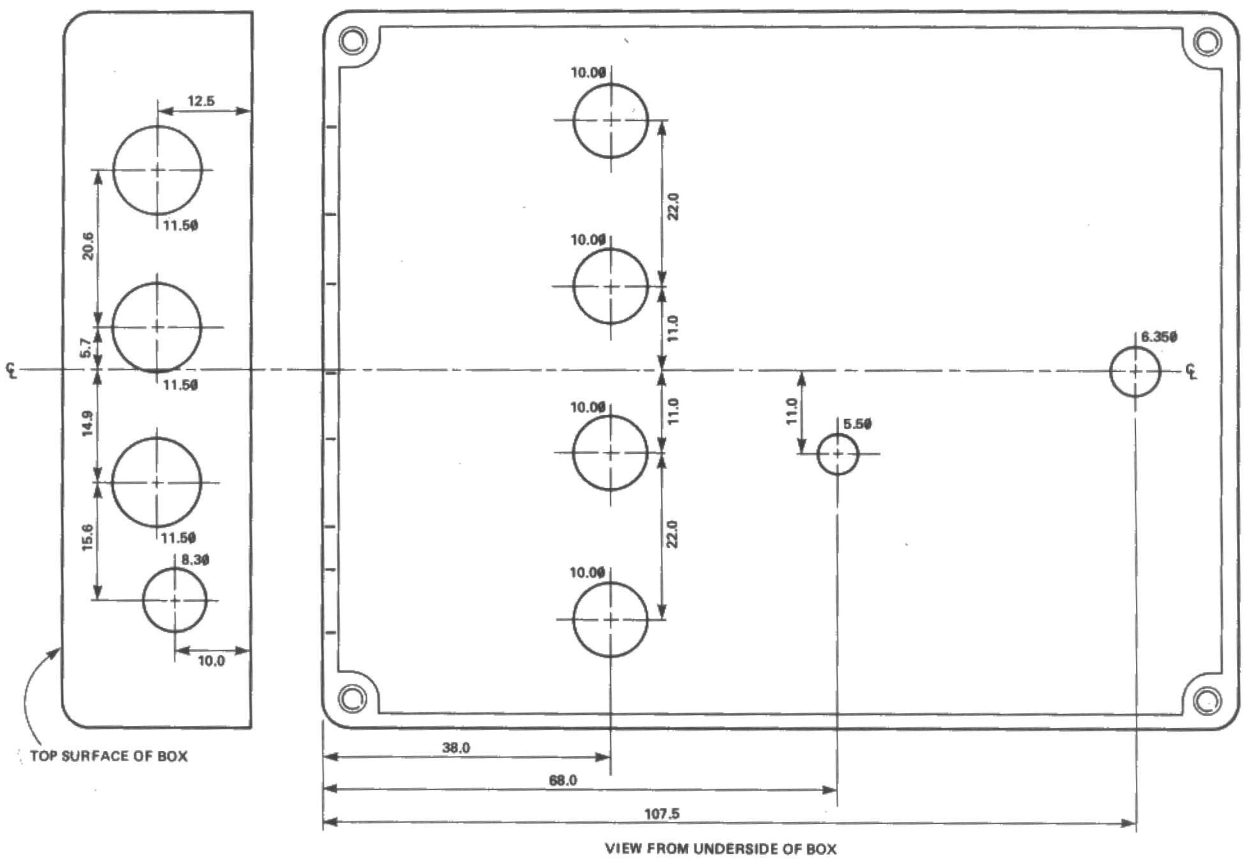


Fig. 4 The case drilling details.

peak. With the rate control fully clockwise this frequency should be about 10Hz, and fully anti-clockwise it should be about 0.1Hz.

Connect the scope to IC3 pin 14, and check for a waveform similar to that shown in Fig. 3. PR1 adjusts the shape of this waveform, and PR2 its offset.

Connect the scope to IC5 pin 2. Turn the width control fully clockwise and the rate control fully anti-clockwise. The frequency of the signal should be slowly changing between the previously-set limits of 19.69kHz and 256kHz. Use PR1 and PR2 to make any final adjustment. A frequency-counter cannot be used for this measurement, because the frequency is constantly changing.

The Case

The PCB of the flanger was designed very much with a particular box in mind. Everything fits very snugly. If you cannot get hold of the same type of box, then use a larger one, to avoid cramping the components. Drill the box as shown in Fig. 4. Again, if using the same type of box, take care to get these dimensions right, since there is not a lot of room to spare inside and the sockets must line up with the holes on the rear of the box, and the switch with the 6.35mm hole on the top.

Rub down the box with wet'n'dry paper. Clean the box thoroughly, prime it, then paint it in the desired colour. Dry-transfer lettering can be applied when the paint is dry, and a coat of Let-fix or Letracote applied to protect the lettering.

If the switch was soldered to the PCB, remove it, and fix it loosely in position in the appropriate hole in the box. Don't tighten it up yet. Fix the potentiometers to the box (a nut and a shakeproof washer on the inside, a nut on the outside).

With a fibre-washer (supplied with the sockets) on each of the three jack-sockets, offer the PCB up to the box, passing the sockets through the holes in the rear of the box. Gently move the PCB and switch around until the switch pins line up with the holes in the PCB. Solder the switch to the board, and tighten the switch from the front. Also, tighten the potentiometers and fix the securing nuts to the jack-sockets (the small socket is not fixed to the box).

Add the switch button, and the control knobs. Glue a piece of thin foam rubber to the inside of the box to prevent the battery moving around. Connect a battery, and fit the baseplate. A piece of rubber may be glued to the base-plate to stop the flanger from sliding across the floor. Test the completed unit by applying a signal of about 1kHz at a few hundred mV to the input socket. The input socket incorporates the flanger's on/off switch. Connect a scope to the input and output alternately, or use a dual beam scope. Press the footswitch until the LED is off, and check that input and output are virtually identical. Press the footswitch again, and the output waveform should start to subtly alter in shape.

PARTS LIST

RESISTORS

R1, 2, 6, 45, 46, 47	47k
R3, 21, 24, 32, 40	10k
R4, 42, 44	470k
R5, 16, 23, 35, 36	22k
R7, 14, 19, 26, 30, 31, 37	100k
R8	200k
R9	33k
R10, 38	150k
R11, 15, 27	62k
R12, 20, 22, 28	3k3
R13, 29	2k7
R17, 43	12k
R18	470R
R24	91k
R33	120k
R34	20k
R39	18k
R41	15k
R48	3k9
RV1	1M0 linear pot.
RV2	2M2 linear pot.
RV3	100k linear pot.
RV4	10k linear pot.
PR1	220k horiz. skeleton preset
PR2	22k horiz. skeleton preset
PR3	47k horiz. skeleton preset

CAPACITORS

C1, 2, 3, 12, 16, 21, 22	10µ 16V radial elect.
C4	1u0 63V radial elect.
C5	2n2 polystyrene
C6, 7, 18, 19	1n8 polystyrene
C8, 20	22n polyester
C9	220n polyester
C10, 17	4u7 40V radial elect.
C11	4n7 polystyrene
C13, 15	150p polystyrene
C14	56p polystyrene
C25, 26	100n polyester
C23, 24	4µ7 16V tan.

SEMICONDUCTORS

IC1	78L05
IC2, 3	TL074
IC4	TDA1022
IC5	4046
IC6	TL082
Q1	BF244A
Q2, 4	ZTX500
Q3	ZTX300
D1, 2	1N4148
LED1	miniature red LED with mounting bezel.

MISCELLANEOUS

SK1	3.5mm miniature jack-socket, PC mounting, with switch
SK2, 3	¼" stereo jack sockets, PC mounting
SK4	¼" stereo jack socket, PC mounting, with switch
SW1	SPDT alternate action push-button switch, panel mounting

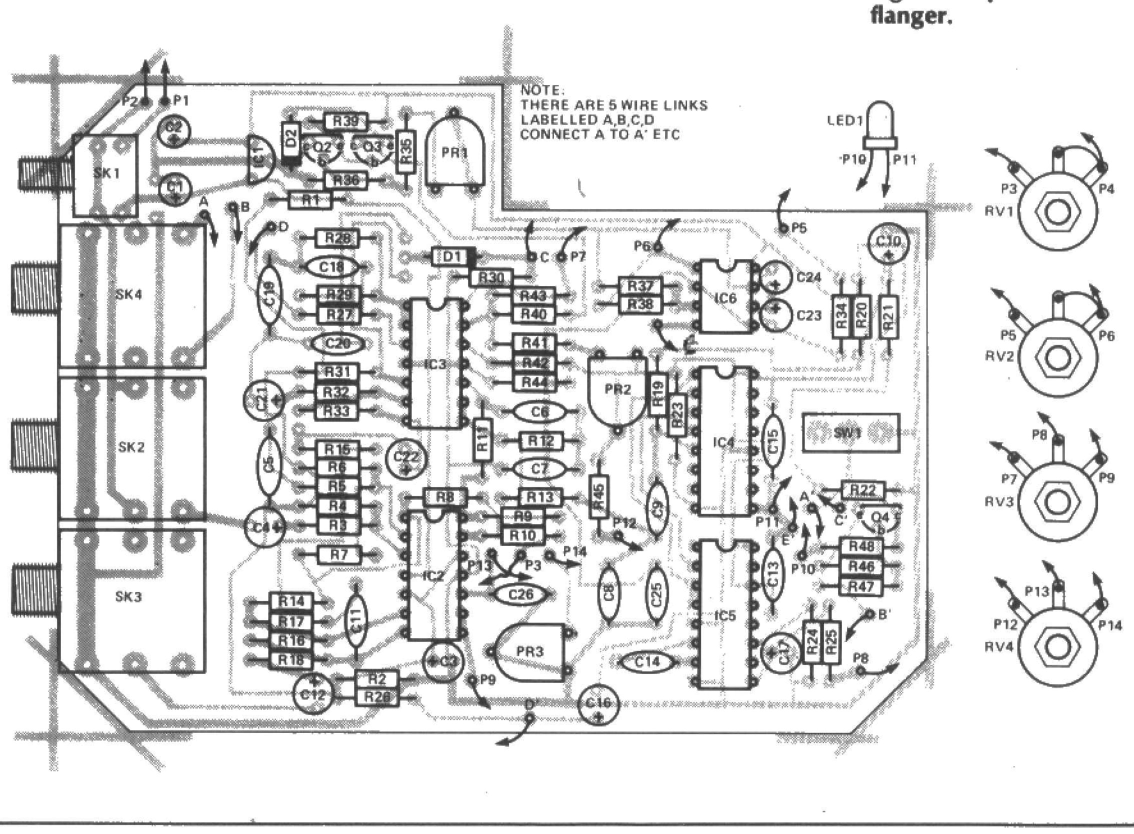
PCB: case; knobs; battery connector; two 20mm pillars, with screws to fit; IC sockets; 9V battery, PP3 or similar; connecting wire; thin foam rubber; rubber sheet for base.

BUYLINES

The ¼" jack sockets used in the prototype are made by Cliff and are designed for PCB mounting. They are not readily available in small quanities but their pin spacing is the same as that of Cliff's panel mounting ¼" jack sockets which are available from Electrovalue. The panel mounting type have solder tags with eyelets rather than pins, but it is a simple matter to cut away one side of the eyelet so as to leave a pin narrow enough to suit the holes in the PCB. Other makes of jacket socket available from other suppliers may also be suitable if so modified but we have not tried this.

The potentionmeters used are also supplied by Electrovalue and are from their P20 range. Electromail stock a suitable switch (catalogue number 339-241) and a 15mm button for it (catalogue number 339-279 for a pack of three) but they do not stock a shroud as used on the prototype. A switch with a shroud is available from Electromatch for £4.15 including post and packing. The part numbers are MPA106D for the switch, C23 for the button and G13 for the shroud and you can contact them on 0403 – 814111 to obtain up-to-date ordering information. The box is made by STC and is type number 73399B. It costs £1.97 plus VAT but inclusive of post and packing from STC Electronic Services Ltd, Edinburgh Way, Harlow, Essex CM20 2DF. All of the other components are available from our regular advertisers. The TDA1022 is available from Maplin. The PCB will be available from our PCB Service.

Fig. 5 Component overlay for the flanger.



ETI

DIGITAL AUDIO SELECTOR

Andy Armstrong completes this project with a description of the audio board and power supply construction, and suggests an alternative arrangement for those who wish to make use of all eight channels.

The completed signal selector should function very well. There should be no detectable crosstalk between signal sources even with the volume control turned to maximum and the input selector switched to a silent channel: for example, with the cassette recorder on pause while another channel is playing. At that setting of the volume control on the prototype pre-amp, the speakers would be overloading. Many systems using mechanical switching give a much inferior performance in this respect.

Crosstalk to unconnected inputs does occur, but this is due to stray capacitance between the inputs rather than to stray feedthrough to the output. Once an input is connected to a signal source with a medium or low output impedance, crosstalk disappears.

Oops!

Since writing last month's instalment, some necessary changes have come to light.

The only significant error related to the power supply to the disc equalizers. The supply connections used in the circuit diagram were taken from an old data sheet which has been found to be incorrect, while the diagram of the pin-out was taken from a later, corrected version. Just reverse the + and - signs on the circuit diagram of the disc equalizer and all will be correct. This does not affect the PCB.

Optional Components

To avoid confusion, component numbers from the left hand channel only will be used wherever possible.

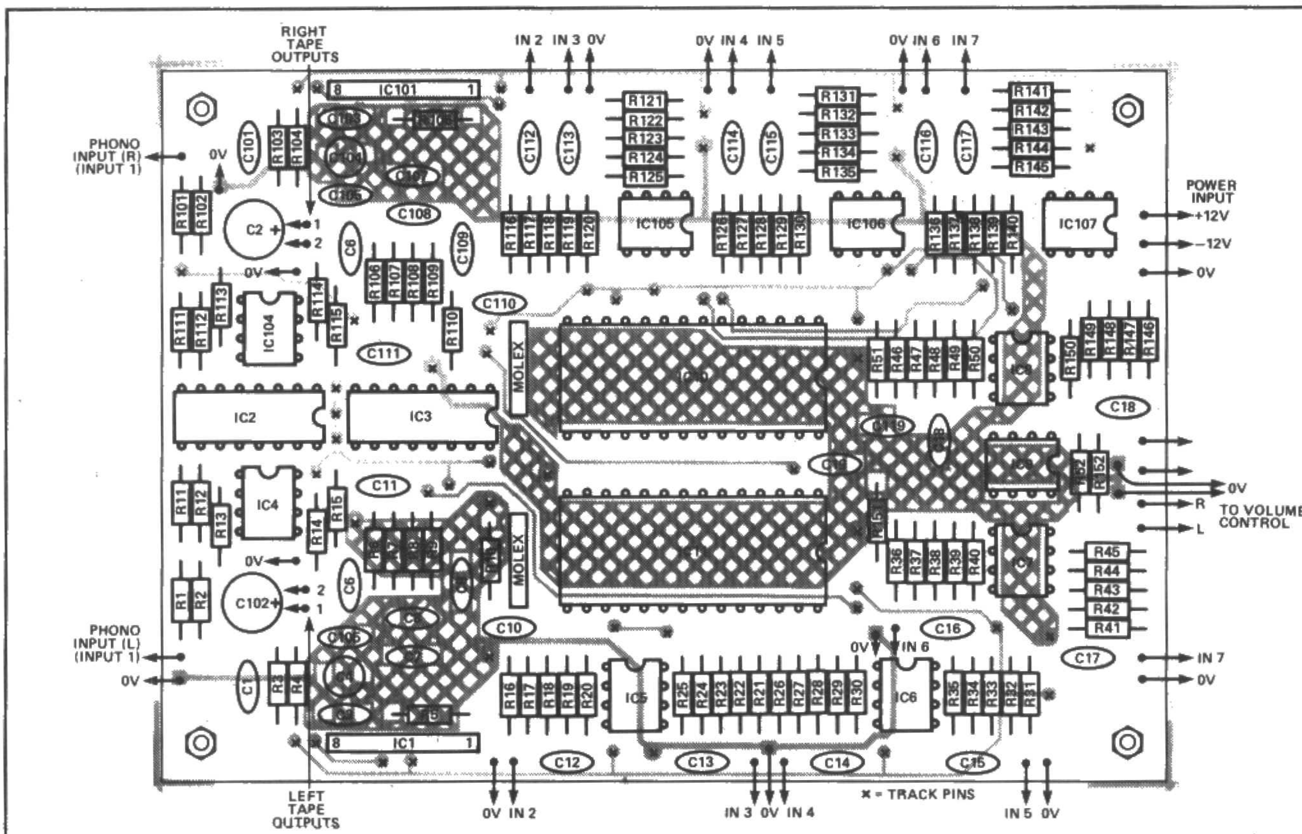


Fig. 1 Component overlay for the audio board, the circuit of which was given last month.

The PCB has been designed to accept a number of optional components, many of which may not be used in any given application. As a result of testing, four of the components designated as optional last month must now be regarded as necessary, C19 — C119 and R51 — R151 should be fitted in all cases, because the disc preamp gives a significant output offset for several seconds after the unit is switched on. It could be harmful to feed this to the next stage or the power amp.

Moving to the inputs, there is one optional resistor in the disc equalizer. R1 may be added to lower the input impedance without affecting the low frequency response of the stage. Because most magnetic cartridges prefer an input impedance of about 47k, R1 would normally be fitted, and would have a value of 100k.

All the remaining input buffers are similar. R16 will lower the input impedance, although this is usually unneccessary. It might be 100k or so. The input buffer stages are also provided with optional attenuation or gain, to cater for unusually high or low output signal sources. Some tuners, for example have a low enough output level to benefit from some extra amplification.

If gain is not required, R20 should be replaced with wire link, and R14 omitted. If gain is required, both R14 and R20 should be fitted. The gain provided is calculated by the formula R20/(R14+R20). The range of resistor values is not important, but as a guideline, R20 should be in the range 4k7 to 47K, the higher values being appropriate to higher gains. Of course, the higher the gain used, the more non-linearity will occur at high frequencies, but gains of up to five should prove no problem.

Attenuation might be useful on one auxiliary input to allow, for example, the earphone output of a radio to be fed in to allow recordings to be made from medium wave. The amount of attenuation is given by the ratio of R17 to R18. The values should be chosen so as to keep the series resistance, R17 + R18 to approximately 100k. If attenuation is not required, R17 should be replaced by a wire link, R14 should be omitted and R18 should be left in place. R16, 17 and 18

PARTS LIST — AUDIO BOARD

RESISTORS

R1, 101	100k
R2, 8, 12, 15, 18, 23, 28, 33, 38, 43, 48, 102, 108, 112, 115, 118, 123, 128, 133, 138, 143, 148	100k
R3, 4, 103, 104	330R
R5, 105	47k
R6, 106	6k8
R7, 107	1k0
R9, 109	2k2
R10, 110	1k5
R11, 111	10k
R13, 14, 113, 114	470R
*R 16, 17, 19, 20, 21, 22, 24, 25, 26, 27, 29, 30, 31, 32, 34, 35, 37, 39, 40, 41, 42, 44, 45, 46, 47, 49, 50, 116, 117, 119, 120, 121, 122, 124, 125, 126, 127, 129, 130, 131, 132, 134, 135, 136, 137, 139, 140, 141, 142, 144, 145, 146, 147, 149, 150	optional (see text)

CAPACITORS

C1, 12, 13, 14, 15, 16, 17, 18, 19, 101, 112, 113, 114, 115, 116, 117, 118, 119	470n polyester
C2, 102	470µ 16V radial electrolytic
C3, 103	100p, 0.2" pin spacing
C4, 104	6n8
C5, 105	2n2
C6, 106	680p
C7, 107	33n
C8, 108	1n0
C11, 111 optional*	470n polyester

SEMICONDUCTOR

IC1, 101	HA12017
IC2	DG308
IC3	4051
IC4, 5, 6, 7, 8, 9, 104, 105, 106, 107	5532
IC10, 11	DG507A

MISCELLANEOUS

PCB; 2 x five way Molex connectors; wire, solder.

determine the input impedance, so R18 should be chosen with that in mind. It should probably not be less than 100k.

The remaining optional components are C11 and C111 on the outputs from IC110. These are only needed if the pre-amp is to be used with a tape recorder which could be damaged by a short term DC offset on its inputs. Their value is 470n.

Optional Channels

As well as having optional components in each channel, the switcher has optional channels. The PCB is laid out for eight channels, but components for unwanted channels can be omitted completely.

If only six channels are to be used, IC8 and its associated components can be omitted (see ETI, December 1986, p.49). Unfortunately, the strictures of a practical PCB layout required the use of ½ of each of IC7 and IC107 for the left and right channels of input 6, so only the passive components for input 7 can be left out. The appropriate components to omit may easily be identified from the tables of component numbers on the circuit diagram shown last month (p, 49, Fig. 5).

If you are deterred by the cost of the DG507s, and you do not need the fancy tape monitoring system, then IC10 can be left out, and C19 and C119 linked to pins 28 and 2 respectively of IC110. In this case, only one row of pushbuttons will be needed, and it will be impossible to monitor the tape while a recording is being made. The howl-round lock-out will still work, however. It will only be possible to record what you are listening to at the time. Some people may not consider this a handicap.

More Choices

If you wish to use all eight of the inputs, the latch board shown in part one (ETI, November 1986) will not be suitable. The circuit of a suitable latch is shown in Fig. 2. No PCB layout is provided, but experience constructors should have no difficulty using Veroboard.

To test this piece of circuitry, only a DVM and a power supply is needed. The first thing to do is to try it out and see if the correct LED lights up as each switch is pressed and at the same time to check the binary outputs with the DVM to check that the correct binary output is given for each switch position.

If the unit does not work correctly first time, the way to locate the fault is to use the DVM to check the logic levels on each gate as the corresponding switch is operated, and compare what happens with the description in the How It Works section. Any

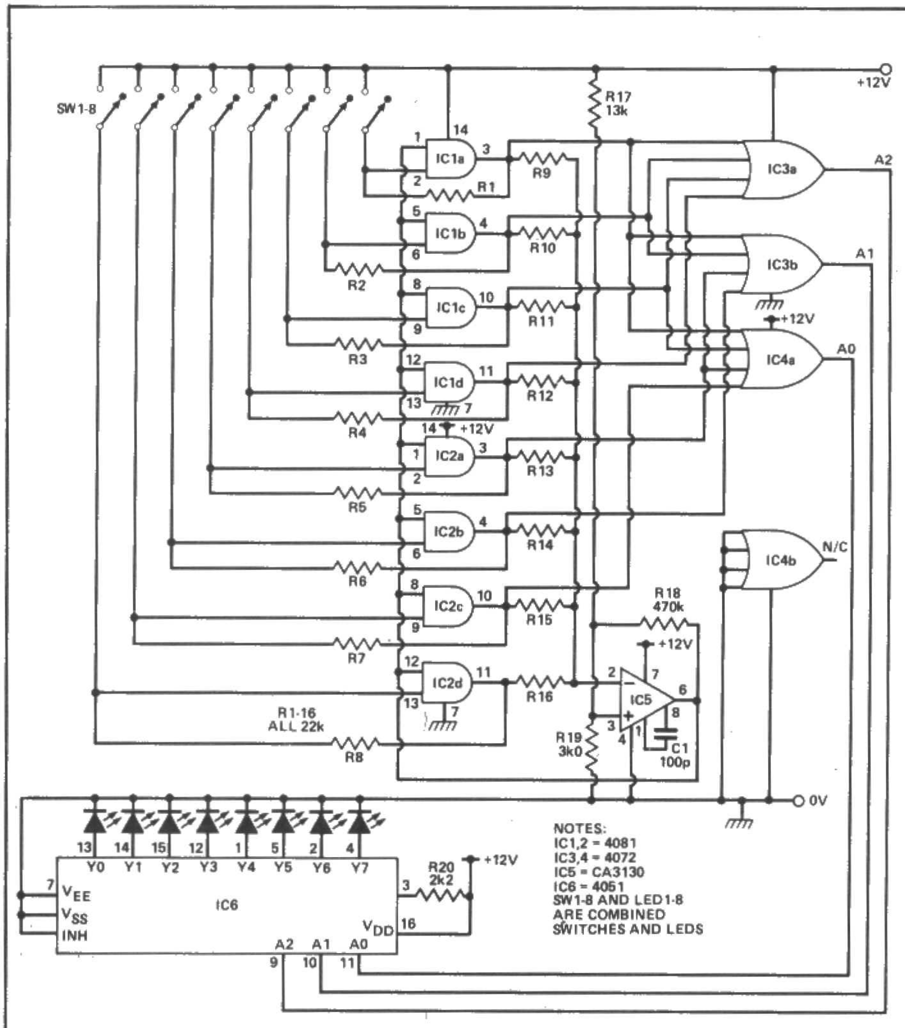


Fig. 2 Circuit diagram of an eight-way latch.

HOW IT WORKS — 8-WAY LATCH

The eight way latch works on a totally different principle from the 6-way latch described in part one. The earlier latch circuit stores the channel number in binary form. This one stores the channel in one-of-eight form, and then converts it to binary for connection to the audio switch PCB.

The conversion to binary is conventional. The connections of the four input OR gates correspond with the 1s in the respective columns of a threebit binary truth table. Therefore the outputs of the gates correspond with whichever row is selected by the one of eight inputs. The truth table (Table 1) shows this pattern clearly.

The one-of-eight latch uses two input AND gates wired so that one input is always at logic 1, and the other is normally at the logic level of the output. A 3130 op-amp is wired as a comparator with one input fed from resistors connected to the CMOS gate outputs, and the other set to a voltage level between that received from the CMOS gates when one of them is at logic 1 and two of them are at logic 0. When the output of the 3130 switches to logic 0, it forces all the CMOS outputs to logic 0. When this effect propagates round the system, the comparator switches back to logic 1.

In this way, no more than one of the outputs of the 4081s is permitted to be at logic 1. For example, if output 1 is at logic 1 and the output 2 switch is pressed, then the two outputs will reach logic one momentarily. The comparator output will now force all outputs to logic 0 momentarily and output 3 will switch to logic 1 to remain in that state. In this way the channel number has been changed in the time taken for a few gate propagation delays.

A2	A1	A0	CHANNEL No.
0	0	0	1
0	0	1	2
0	1	0	3
0	1	1	4
1	0	0	5
1	0	1	6
1	1	0	7
1	1	1	8

PARTS LIST — 8-WAY LATCH

EIGHT WAY LATCH (optional)
(No PCB Layout is given.)

RESISTORS
16 x 22k; 1 x 470k; 1 x 3k0; 1 x 2k2; 1 x 13 k.

SEMICONDUCTORS
1 x 4081; 2 x 4072; 1 x CA3130; 1 x 4051.

OTHERS
1 x 100p capacitor; 8 x LED/Switches (see diagram).

fault should then stand out clearly.

Construction

Methodical assembly should ensure that most switchers work smoothly first time. Link all the holes connecting to top tracks, using track pins or pieces of tinned copper wire. Some of the holes connecting to top tracks have no connection to anywhere else on the underside. These connections are intended to be used for top soldering the braid of the screened lead used for signal connections, but if you prefer soldering to pins then insert them.

It is advisable to build and test the disc equalizer stages first. Once these stages are built, connect up a ±12V power supply. If you have a signal generator and an oscilloscope then a signal check is in order. After, or instead of, the signal check, a DVM should be used to measure the output offset of the stage — this should be low. If the offset is likely to reverse polarize C2, then C2 should be unsoldered and inserted the other way round so that it is correctly polarized

Once the disc equalizers are correct, the rest of the components can be soldered in. When wire links are needed (for example, the R17 position) there may be top tracks. You will need to insulate the wire links or to use zero ohm resistors in those cases. Zero ohm resistors were used on the prototype.

IC10, IC110, and IC3 are the components most vulnerable to static damage, so they should be fitted last. The unit can then be powered up on its own and the offsets of all the buffers checked. If any of them is high investigate it for a short circuit.

Before connecting inputs and

outputs, the switching system should be checked. If you are using the digital latch described in ETI, November 1986 you will notice that the connections to A0 and A2 are reversed on the switcher board compared with the latch board. The wires in the connecting leads should be swapped over. This can best be done by hard wiring the lead at the latch end, and using a Molex connector on the switch board end. In this way, the connections to the latch boards can be kept out of the way while the inputs and outputs are wired up.

Wiring Up

All the signal connections should be made with good quality screened lead. The braid should be earthed at both ends, but the earths of different input channels should be isolated from each other. The existence of multiple earth paths could cause slight crosstalk.

Because there are so many connections to the PCB, the wiring must be done tidily and methodically, to avoid burning some of the earlier leads when fitting later ones. An extremely neat wiring job can be achieved with only a little effort (and a number of cable ties).

When the wiring up is complete, including connection of the power supply, you should have a fully working audio switcher.

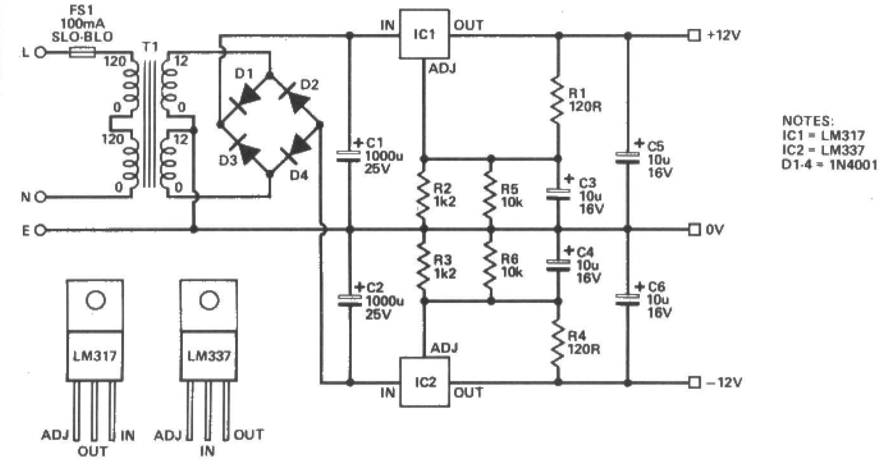


Fig. 3 The circuit of the regulated power supply.

Power Supply

The unit can be incorporated into a complete amplifier with its own power supply. In this case, voltage regulators should be added to provide ±12V. A 7812 and a 7912 would be suitable, but better would be an LM317 and a LM337 wired as shown in the power supply circuit of Fig. 2.

Whichever voltage regulators are used, a heatsink should be fitted at least to the positive one, and care should be taken that the tabs do not come into contact with the metalwork of the amplifier.

If the selector is to be built into a separate case, perhaps with other modules to form a complete pre-amp, a power supply will be needed. The circuit of Fig. 3 was designed for the purpose, and a PCB layout for it is provided. The voltage regulator ICs chosen for this power supply give a better ripple rejection than 78/79 series regulators, and this point is very important in sensitive audio equipment.

Construction II

Construction of the power supply is qute straightforward. The fuse clips will only accept a fuse if they are fitted the right way round, so look at them carefully before fitting.

The board has been laid out specifically to use the TO202-case version of the voltage regulators because this is cheaper, but the standard TO220 type can be used if the TO202 type is not available. The heatsinks differ: TO202 types have a fixing hole in the centre, TO202 types have the hole towards one end.

Heatsinks are not strictly necessary if the power suply is only used for the selector, but it might be a good idea to fit them anyway to allow enough power to add further circuitry. Regulators should be bolted down to provide strength, and the bolts should be tightened before the pins are soldered. If heatsinks are not used on T0202-style regulators, then a nut should be used as a spacer to avoid bending the tab.

Testing is a doddle — but first check that all the electrolytics are in the right way round. The board is laid out so that they should all be the same way round. Then connect up the mains and switch on. Use a DVM to measure the output voltages and the voltages on C1 and C2, which should be about ±18 to ±20V.

HOW IT WORKS — PSU

This supply is designed to provide a modest power output, but with excellent regulation and ripple rejection. The PCB is laid out to take a 6VA transformer. Bearing in mind that a transformer should be de-rated when run with a rectifier load and that there are losses in the voltage regulators, about 3 watts should be available for the load. This is more than enough.

For the sake of round figures, assume that the maximum load current is 100mA. The ripple on the reservoir capacitors can be calculated approximately from the formula, voltage change =It/C, and is 1V. Given that the average voltage on the reservoir capacitors is 17V or more, the voltage will not dip low enough to inconvenience the regulator ICs.

The regulator ICs themselves are of a type in fairly common use, but they are not so widely used as the 78/79 series Ics

The LM317 series ICs work by maintaining a constant 1.2V between the output and adjust terminals. Let us take the positive regulator, IC1, as an example. The constant 1.2V is maintained across R1 which has a value of 120R, so the current flowing is a constant 10mA. This current, plus a very small contribution from the adjust terminal, flows through R2 and R5, which have a net value of 1.071428571k. The voltage across these resistors is approximately 10.7V, so the output of the circuit, at 1.2V higher, is 11.9V. This is close enough!

Capacitors C3 and C5 serve to reduce the ripple and improve the transient response of the circuit. The resulting performance is superior to that of 78/79 series regulators, and in practice no hum is audible on the sound under any circumstances.

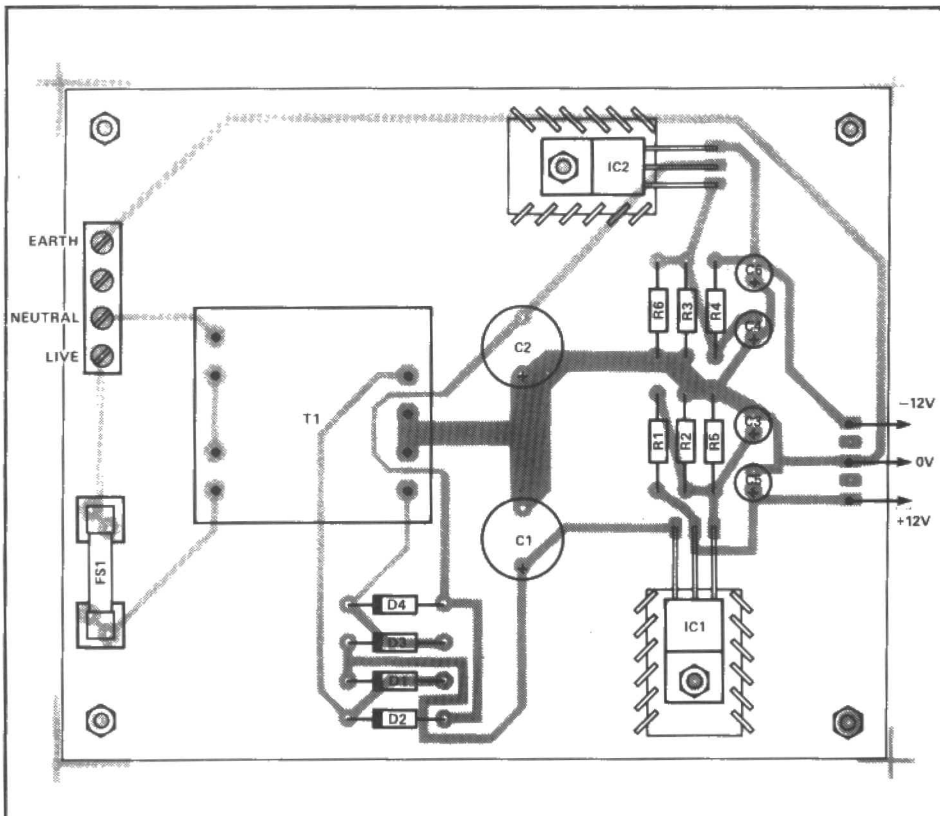


Fig. 4 Component overlay for the power supply board.

PARTS LIST — PSU

RESISTORS

R1, 4	120R
R2, 3	1k2
R5, 6	10k

CAPACITORS

C1, 2	1000u 25V radial electrolytic
C3, 4, 5, 6	10u 16V radial electrolytics

SEMICONDUCTORS

IC1	LM317MP
IC2	LM337MP
D1-4	IN4001

MISCELLANEOUS

FS1	100mA slow blow;
T1	120-0, 120-0 RS type 207-756;

PCB; 2 x fuse clips; 2 x M3 nuts and bolts; 2 x 21°C/W heatsinks (Maplin); four way screw terminal; five way 0.1in locking wafer.

ETI

THE ETI LEDSCOPE

Tony Ellis lights up your life with 140 LEDs in this simple but instructive design which acts as an oscilloscope, simple voltmeter and ohm-meter, too.

Of course, the Ledscope will not equal the performance of a cathode ray oscilloscope, but it costs considerably less, is easy to construct, portable and can display waveforms at the lower end of the frequency spectrum surprisingly well. It could also be of educational interest, as it makes clear the workings of one of the most useful pieces of test equipment, and can give valuable — and cheap — hands-on experience.

The Ledscope could be built by any moderately competent constructor and will be rugged enough for most workshop environments. Its limited frequency range is nonetheless adequate for much audio work.

Leading Lights

The display consists of four 7 x 5 packaged LED arrays which form the 140 element 'screen'. For the scope function vertical (y) position depends on a bar-graph IC (the LM3914) used in dot mode. The IC suppresses all but the leading light of a bar of LEDs. The timebase (or x-position) is provided by a 14-line decoder (the 4514) driven by a clock which sequentially pulses the array turning on each column in turn.

A dot of light may be made to appear to move along the display giving a trace which varies in height with the input voltage. Only one LED is illuminated at any one time, but persistence of vision results in us seeing a continuous curve showing the waveform of the varying input.

Higher or lower frequencies can be captured by varying the timebase clock frequency, which is divided down by the decoder circuitry. No trigger is incorporated in the circuit largely because it was felt to be unnecessary and complicating. At the kind of frequencies the Ledscope can actually handle, it is possible to very closely match clock and input frequencies to give an almost stationary waveform.

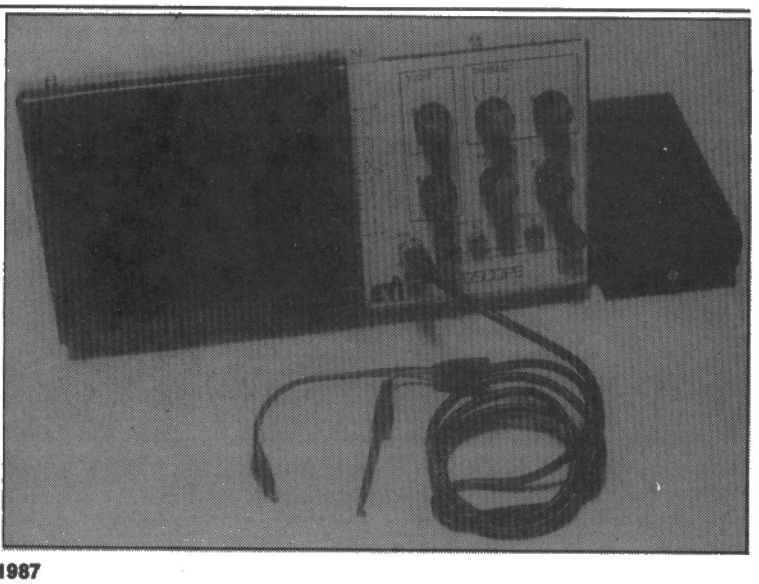
To operate with low voltages and give the scope a high input impedance, a CMOS op-amp is used for the input stage. This section is the y-amplifier. Gain is controlled by a panel-mounted potentiometer. Experiementers may wish to combine this with switched attenuation to provide a series of ranges.

Since the bar-graph IC we're using can only accept a positive input, while the scope will be required to display AC waveforms, a second op-amp is used to add a constant voltage (a DC offset) to the output of the y-amplifier. This shifts the whole trace upwards. A zero volt trace will now appear around the centre of the display — subject to the y-shift potentiometer setting. A positive input voltage causes the upper half of the display to illuminate, and a negative input voltage turns on the lower half.

In volt-meter mode, the device acts as a simple DC meter with two ranges: 0-10V and 0-50V. Only one column of the display is activated and the bar-graph is in dot mode so that LEDs illuminate in sequence up a single column in response to applied voltage.

In ohm-meter mode, the device can be used to indicate resistance. The ohm-meter can be calibrated for different resistance ranges using the 'ohm adjust' control. Only one column of the display is activated. The bar-graph is in bar mode so that input *conductance* is directly related to the length of an illuminated column. A short-circuit should light-up all the LEDs in the column.

The 3914 can provide different LED currents and resulting display brightnesses. This is used to advantage in the Ledscope. Full current (20mA per LED) is used for the scope function to ensure a clear bright trace. Low current (7mA per LED) is used for the ohm-meter to reduce current consumption when up to 10 LEDs may be simultaneously illuminated.



The Ledscope with probe and battery box.

Construction

Provided you obey a few simple rules and take care, your circuit should work first time. Inevitably, too much haste leads to carelessness and disappointment. The main points to remember are:

- Ensure components are inserted the right way round. This is essential with semiconductors, as you will seldom get a second chance if they are inserted incorrectly. If in doubt follow our overlay diagram (Fig. 2) and use

the circuit diagram for confirmation.

- Only use a miniature soldering iron of 25W or less, and remember to wipe the tip regularly with a wet sponge to remove excess solder and flux. Do not overheat components.

Begin construction by installing the wire links. Positions are indicated on the kit PCB by a white line on the legend.

Cut each of the 25-way DIL socket strips listed in the Parts List into three seven-way DIL strips, taking care to cut the eighth socket each time. Insert these in to the PCB. Make certain that all sockets are installed in the same direction, because the socket pins are off-centre which can result in a misaligned display. Next solder in place the six IC sockets — also the right way round, of course.

Solder the resistors in place (note: R4 should be laid flat), then follow with the capacitors. Next insert all diodes, making sure that the OA47 is in D1 position. Solder them and the fuse carrier and trim all surplus leads.

Finally insert the ICs and the LED arrays into their prepared sockets. Refer to Fig. 2 for the orientation of the LED arrays, but check positioning with the ICs, too.

HOW IT WORKS

IC6a (Fig. 1) forms a non-inverting amplifier with DC being fed directly and AC via capacitor C4. The gain of this stage is controlled by RV1 and ranges from unity to about 20. R10 sets the input impedance of the scope to about 1M0 since the effect of IC6a's impedance is negligible.

The display driver (IC1) requires a positive input, but the signal on pin 1 of IC6a may well be negative. The solution is to offset the input signal so that IC1 only ever receives a positive voltage.

A constant negative voltage is taken from the wiper of RV2 to the inverting input of IC6b, while the output of IC6a is taken to the non-inverting input of IC6b. With R4, 5, 6 and 7 all equal, the arithmetic of op-amp differential amplifiers shows that the output of IC6b will be (V+) − (V−), where V(+) is the voltage at the output of IC6a and V(−) is the voltage at the wiper of RV2. Since V(−) varies between −9V and 0V, the effect is of a screen-movable zero trace that will move upwards in response to a postive scope input and downwards in response to a negative one.

The constant negative voltage is provided by the voltage inverter, IC5, which produces a negative output of equal magnitude to its postive input. This output also provides the negative rail for IC6.

The timebase clock is formed by IC4a and b and the frequency is varied by means of SW2 and RV3. The clock output is sent to IC3, a dual four-bit binary counter on half of which is used. The four-bit output is fed to a 4-to-16 line decoder, IC2, which drives the horizontal axis of the screen matrix. This pulses lines 0 to 13 sequentially and resets IC3 on the 15th count when line 14 goes high. Together with IC1, this provides a simple sample against time display driver with a resolution of 10x14.

IC1 is a dot/bar display driver which drives the vertical axis of the LED 'screen'. The IC contains a voltage divider and 10 comparators that turn on in sequence as input voltage rises. The IC has constant current ouputs so no series resistors are required with the LEDs. Current output is actually determined by R1 and R2 and is switchable to give high current per LED in dot and scope mode and low current in bar mode. The mode is chosen by connecting pin 9 to pin 11 (dot) or pin 9 to the positive rail (bar).

In volt and ohm modes, the 4-to-16 line decoder is inhibited and LED column 13 (the 14th and right-most column) is fed via D2 to give a single column display.

Once you have checked that the board is okay, that everything is correctly in place and that there are no solder bridges, short circuits or breaks in the tracks, you can wire up the panel controls keeping all wires as short as possible (Fig. 2). It's a good idea to cross off

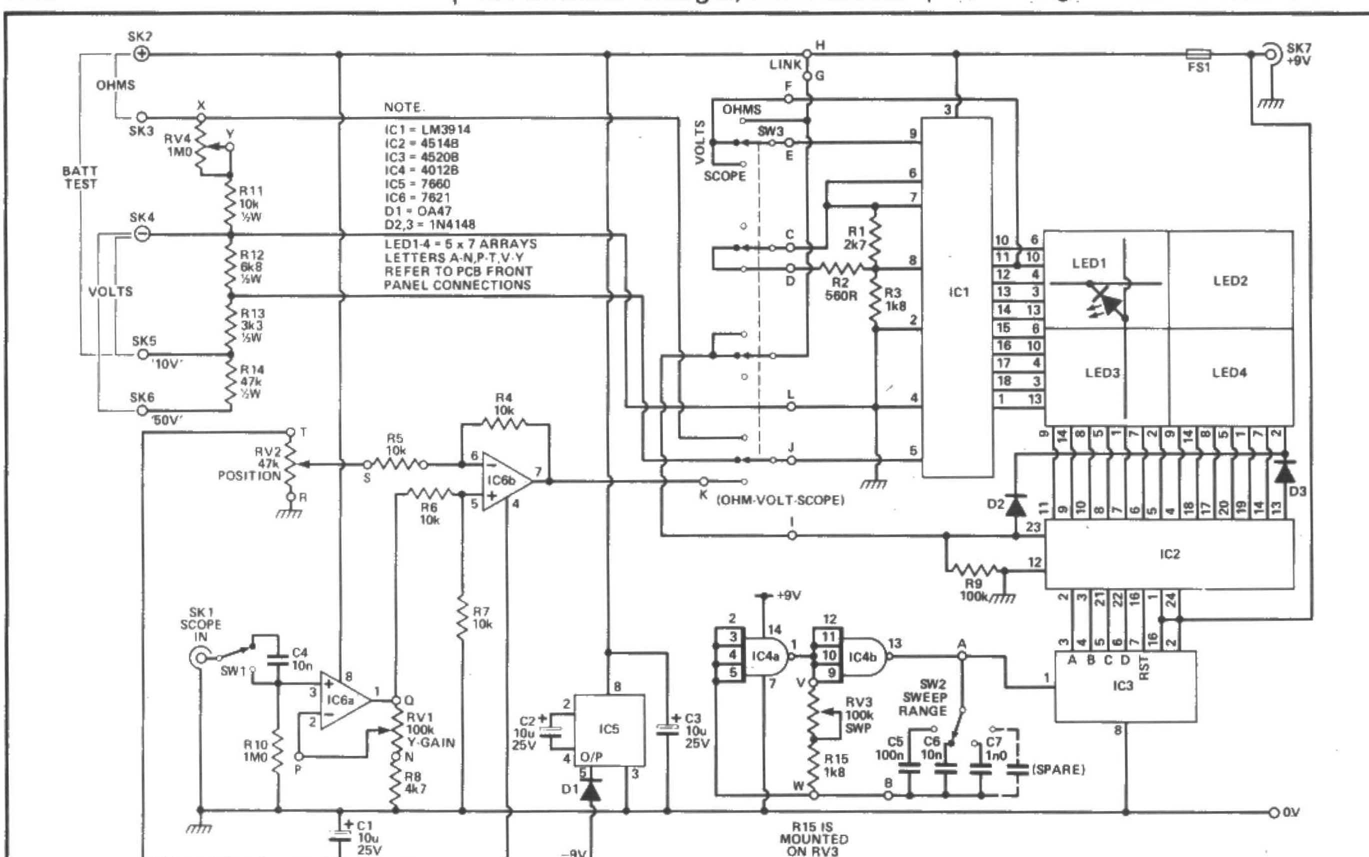


Fig. 1 Circuit diagram.

from the drawing each wire and component as it is assembled. Make sure, too, that the shield on the screened cable from the BNC input socket is soldered to the earth pad provided.

Case Construction

If you decide to build a case like that used in the prototype then you will have to drill and bend perspex. This may seem to be a simple task at first, but if you've never done it before it will require much thought and care.

Perspex can be bent once it has been heated along its bendline. This is usually done on a purpose-built perspex bending rig which the home constructor is unlikely to have access to. The solution used in making the prototype was to replace the rig with a blowlamp and an engineer's vice. Please note: GREAT CARE MUST BE TAKEN WHEN USING A BLOWLAMP TO BEND PERSPEX AND IT SHOULD NEVER BE UNDERTAKEN IN THE HOME.

PARTS LIST

RESISTORS (a ¼W 5% carbon film unless stated)

R1	2k7
R2	560R
R3, 15	1k8
R4, 5, 6, 7	10k
R8	4k7
R9	100k
R10	1M0
R11	10k ½W
R12	6k8 ½W
R13	3k3 ½W
R14	47k ½W
RV1, 3	100k lin
RV2	47k lin
RV4	1M0 lin

CAPACITORS

C1, 2, 3	10µ 25V elect.
C4, 6	10n
C5	100n
C7	1n0

SEMICONDUCTORS

IC1	LM3914
IC2	4514B
IC3	4520B
IC4	4012B
IC5	7660
IC6	7621
D1	OA47
D2, 3	1N4148
LED1, 2, 3, 4	5x7 LED array (LITON 2157 or similar)

MISCELLANEOUS

SW1 SPDT, SW2 4-way, SW3 4-pole 3-way switches; 2x8-pin, 1x14-pin, 1x16-pin, 1x18-pin, 1x24-pin DIL sockets; 3x25-way DIL socket strip; 50R BNC socket; ¼" jack socket and plug; 4mm sockets (2 red, 1 black); 4mm terminals (1 red, 1 black); FS1 250 mA fuse; chassis fuseholder; PCB; short length low capacitance and screened cable; stick-on feet; perspex; aluminium for case; materials for battery box and simple tester (see text).

Perspex is supplied with a backing paper attached. This can be used to draw your bendlines (Fig. 3 gives the necessary measurements). You will notice that the bendlines are 3/16" back from where we want the actual bends to be. This is because a 90°

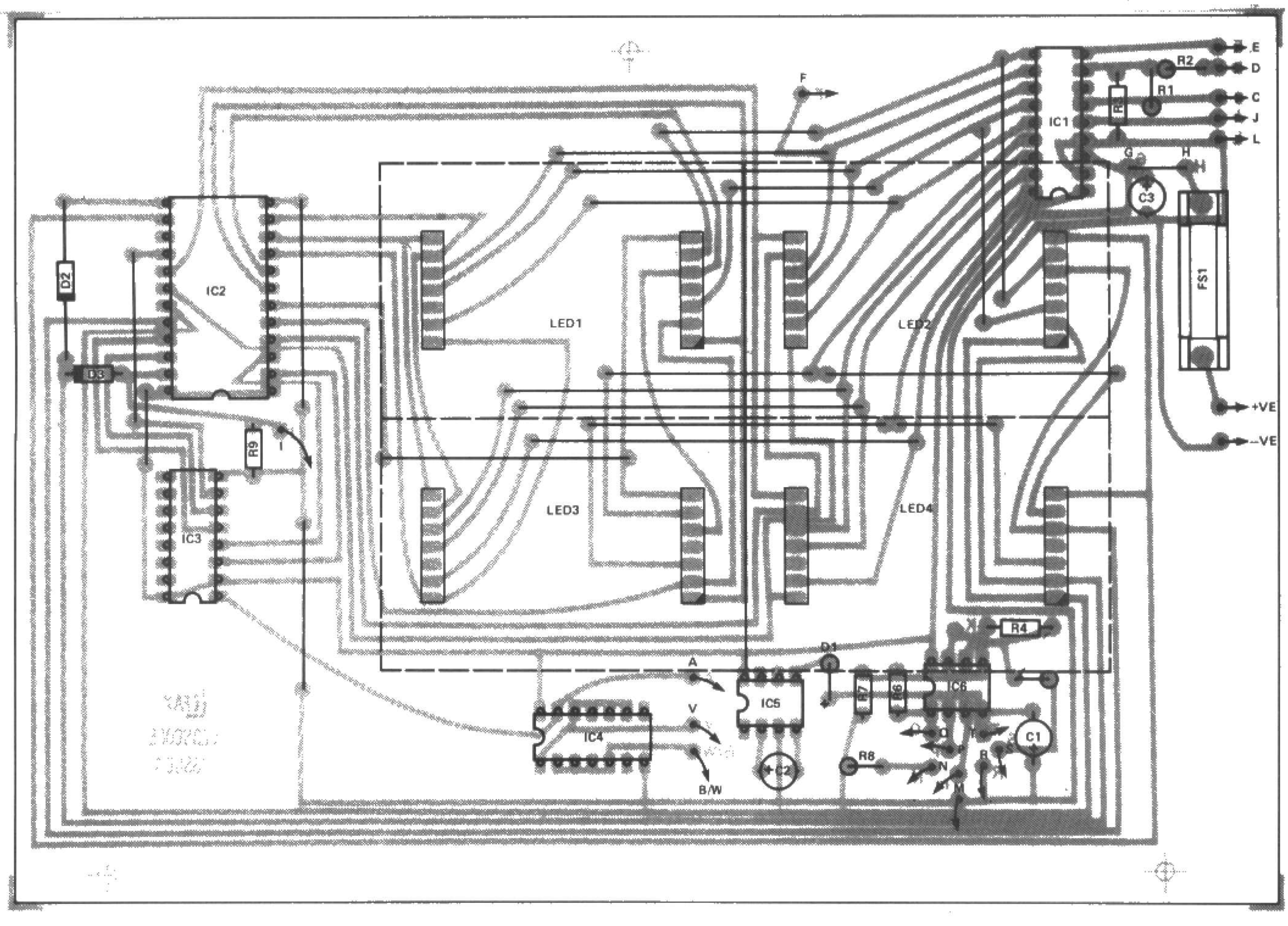


Fig. 2 Component overlay (note modification to PCB which should be incorporated in the commercial kit). The letters correspond to off-board connections (see Fig. 1).

bend in perspex takes in that much material in its curve.

Before you start the bending, get two pieces of 1" x 1" angle iron (or similar) about 12" long to extend the vice cheeks. Once these are positioned centrally, place the marked perspex into the vice and line the edge of the angle with the marked bendline. Tighten the vice and remove part of the backing paper where the bendline is (about 2" from the angle edge).

Using a low flame, run the blowtorch up and down the angle edge (don't do this too slowly or the perspex will bubble). The perspex will soften and you will be able to pull a 90° bend with your hands. Take the heat away and let the perspex cool and set. Do this with all the pieces and bends necessary.

The aluminium is much simpler to deal with. First mark out the backplates (see Fig. 3 again). Now cut off the areas shown shaded and place the aluminium (longways for backplate A and shortways for backplate B) into the extended vice cheeks, lining up the angle edge with the marked bendline. Apply pressure to the visible portion of the aluminium until a right angle forms.

Now take away the angle iron and cut a piece of wood 5 ¼" long. This is used as a former to bend the remaining edges. You will need one of the angle iron pieces to extend one of the vice cheeks so as to provide a back former.

After you have finished bending the aluminium, offer up the perspex and check the fit. If all's well drill all holes as shown, once again, in Fig. 3. TAKE GREAT CARE WHEN DRILLING PERSPEX AS IT CRACKS VERY EASILY. ONLY USE A SLOW SPEED DRILL.

This is a good juncture at which to paint the aluminium, using ordinary car spray paint on a buffed surface. Now comes the hard bit — producing the control panel. This needs great care as lots of drilling is required.

First cut out or photocopy the legend sheet (Fig. 4 — also supplied in the kit) and use it as a guide. Sandwich the sheet between front panel B and backplate C (Fig. 5). Clamp the sandwich tight. It may help to drill small holes in the centre of the y amplifier pot circle and the negative terminal circle and bolt panel, sheet and plate together with two 4BA screws and nuts.

Carefully drill all the other holes, starting with pilot holes and then increasing their diameters to correspond with the legend sheet. This must be done gradually, stepping through the drill sizes to avoid cracking the perspex. A set of round files will be useful to smooth out the holes and make minor enlargements.

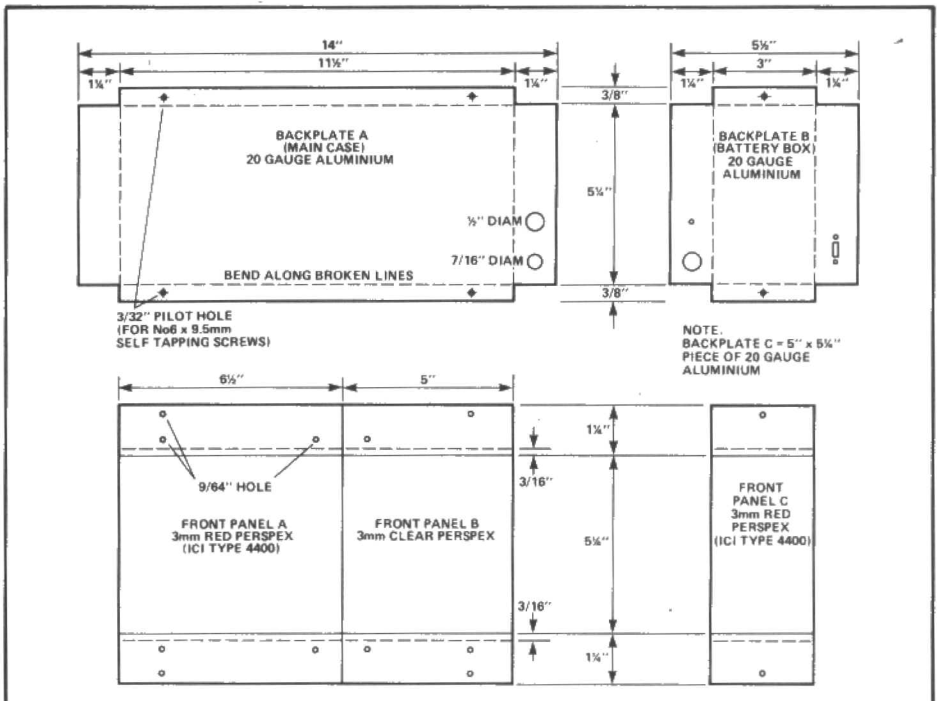


Fig. 3 Case dimensions, cutting and drilling details.

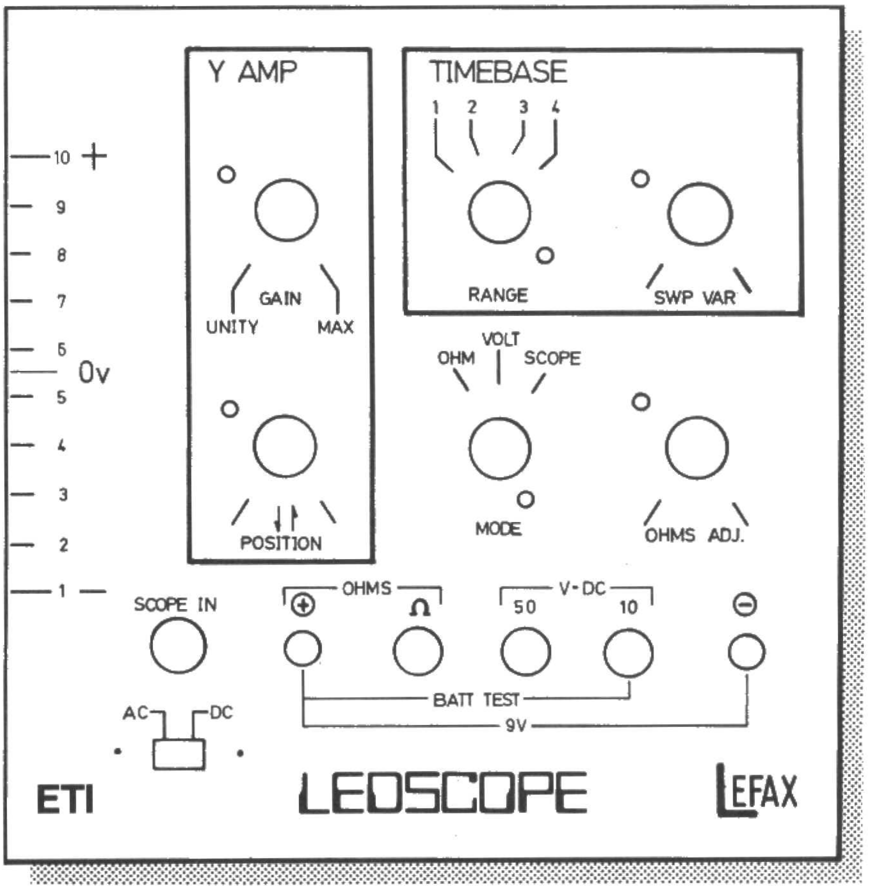


Fig. 4 Panel legend.

When the drilling is complete, install the sockets and tighten the fixing nuts. You can now remove the two 4BA screws and finish off the two remaining holes. After cutting all potentiometer and switch spindles down to ½", mount the pots, switches, terminals and BNC socket. Front panel B is now complete. Now make up the drill and ½" x ½" angle pieces shown in Fig. 5 and assemble front panels A and B as shown.

The battery box can now be assembled from the illustration in Fig. 6. The jack plug is fitted by making a locking nut out of the original plastic cover, using a junior hacksaw to remove ⅛" carefully from the screw-threaded end of the cover.

The two battery holders are glued on to a perspex plate to avoid shorting out the batteries if the holders were to come in to contact with aluminium and also to make the holders easily removable.

The assembled PCB can be fitted to the front panel (Fig. 5, view from A) and the connections made between the board and the control panel (Fig. 2). Keep all interconnecting wires as short as possible. You may have to unscrew and slightly move the PCB while you wire up the BNC socket and switch section of the controls. When wiring is complete, dress the looms to keep them tidy.

Connect up the jack socket using about 9" of two-core cable. Insert and tighten the socket in to the lower side of backplate A. Assemble the main case completely, tightening all screws, and insert the battery box jack. The unit is ready for testing.

BUYLINES

A kit of parts, excluding the case, is available from Lefax Ltd, Unit 6, Genesis Business Centre, Redkiln Way, Horsham, West Sussex RH13 5QH (tel: 0403 54135) at £49.95 incl. VAT plus £2.50 p&p. The biggest problem for those wishing to source their own components will be the LED arrays. You should use the type specified, which have a greater light output than other types which look the same. Maplin type FT61R will not be bright enough. You could always make your own array from 140 individual LEDs — in which case use orange types which are brighter or, if money is no object, ultra-brights.

The other components should not prove problematic. The ICL 7621 is a low-power dual op-amp, but is not critical. It is available from Electromail, Dept. 101, PO Box 33, Corby, Northants NN17 9EL (tel: 0536 204555), but the 353 or 072 should be just as usuable. The prototype case was made from aluminium and perspex which are available from high-street shops who will usually cut them to size for you. Lefax have a number of all-aluminium cases available, which are ready shaped, drilled, painted and legended. Together with an ABS plastic battery box, the cost is £14.95 inclusive of everything, if ordered with the main kit, or £14.95 plus £2.50 p&p if ordered separately. The company also sell a low cost test lead kit suitable for this project (or, indeed, for use with other meters and scopes). The price is £7.95 inclusive for which you get a scope lead with integral probe and BNC plug and a set of 4mm test leads.

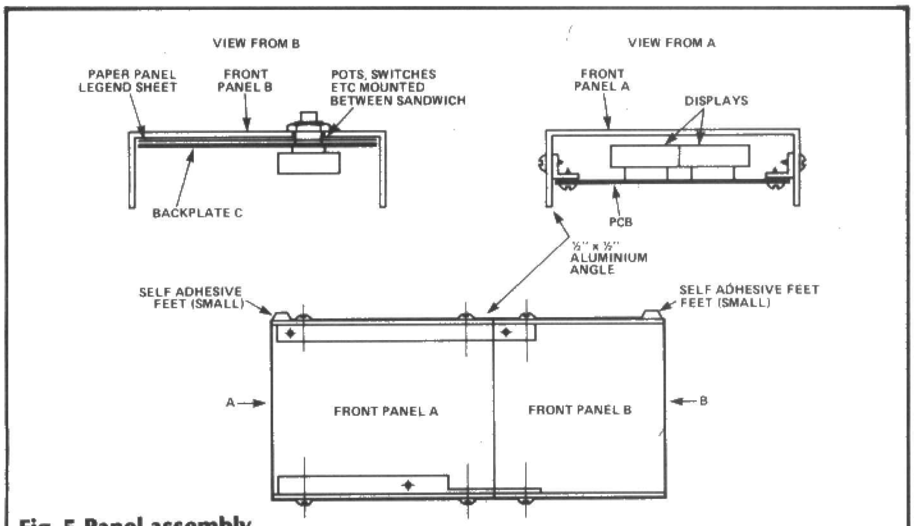


Fig. 5 Panel assembly.

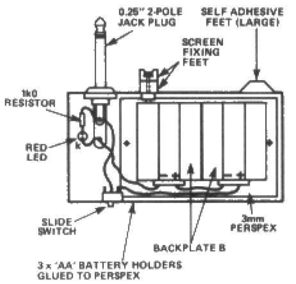


Fig. 6 Battery box.

Testing

Before switching on, turn the y position knob to halfway, the y amplifier (or gain) knob to unity, the timebase switch to '1', the knob marked 'SWP VAR' to halfway and the mode switch to 'SCOPE'. Plug in the scope lead and switch on. A trace should appear around the centre of the screen.

The easiest test is to place the scope lead close to a mains lead. NEVER CONNECT THE LEDSCOPE INPUT DIRECT TO THE MAINS — IT IS POTENTIALLY LETHAL. With the scope lead near a mains supply it should pick up hum. By adjusting y amplifier gain and the timebase ('SWP VAR'), the scope should show a clear sine wave whose amplitude should be adjustable using the y amp control.

To check the meter functions, use appropriate known voltage sources and resistances. In ohmmeter mode, the display should show the right-most column only as a bar.

ETI

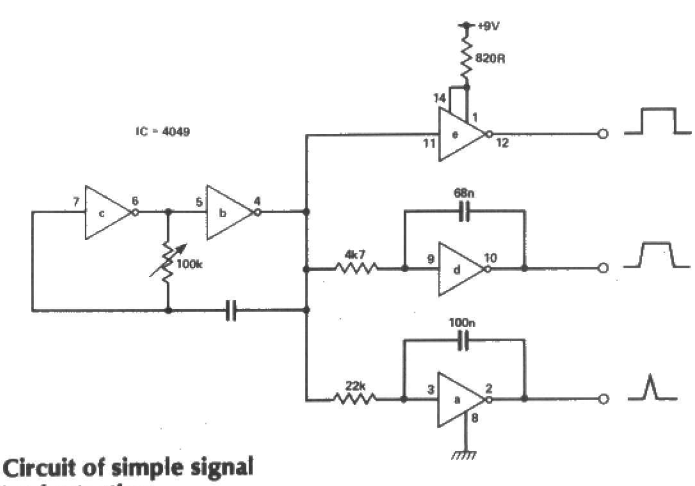


Fig. 7 Circuit of simple signal generator for testing.

COMBINED TACHO/DWELL METER

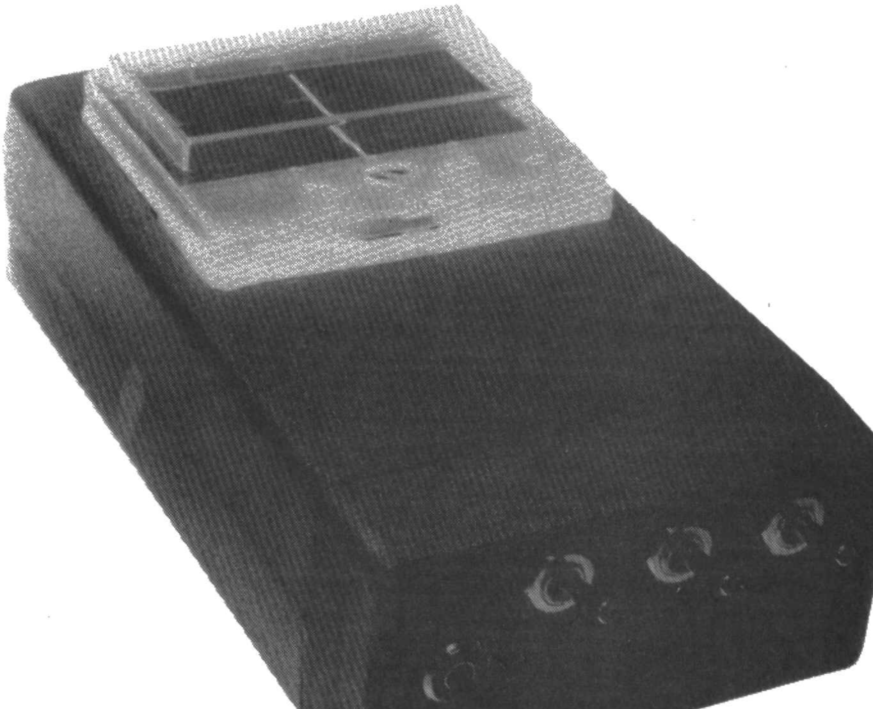
Following our introduction to the LM2917 last month, Paul Chappell comes up with a design that will prove essential to anyone who wants to tune a car engine – two-meters-in-one to bring your auto to the peak of performance perfection.

Choosing a meter movement for this project caused us a few headaches. A good quality movement can cost more than the rest of the project put together, and most types are too deep to fit in a slim, hand-held case. Cheap'n'cheerful meter movements are available — VU meters in particular can be bought for a few pounds — but they suffer from poor linearity, which makes the calibration procedure much more complicated. In the end, we settled on a low cost movement, but you may prefer to buy a good quality 1mA movement, or else use the circuit as an add-on for your multi-meter.

The circuit itself is shown in Fig. 1 and the component overlay and switch wiring details in Fig. 2. It is very simple. When assembling the PCB, make sure to put in the wire links *before* the presets — you won't be able to get them in afterwards. We used a DPDT switch for the on/off function because it provides convenient tags to solder the battery connector to. There is no reason why you should not use an SPST switch instead.

The switches must be miniature types, and must be mounted above centre on the front panel to avoid fouling the trimmers on the PCB when the case is assembled. We drilled the switch holes on centres 10mm from the top of panel.

The test leads consist of a pair of small crocodile clips on a length of twin wire. It is important to get the chips the right way round — it won't affect the tachometer, but the dwell meter will not read correctly if the leads are reversed.



The sleek and sporty lines of ETI's high performance motoring aid.

RV5 in the circuit of Fig. 1 will only be needed if you follow our example and use a cheap meter movement. It can be soldered on to the tags at the rear of the meter. A suitable value for use with the specified type is 200R.

Calibration

If you use the circuit in conjunction with a multi-meter or good quality 1mA meter movement, calibration at one point will be adequate. The circuit

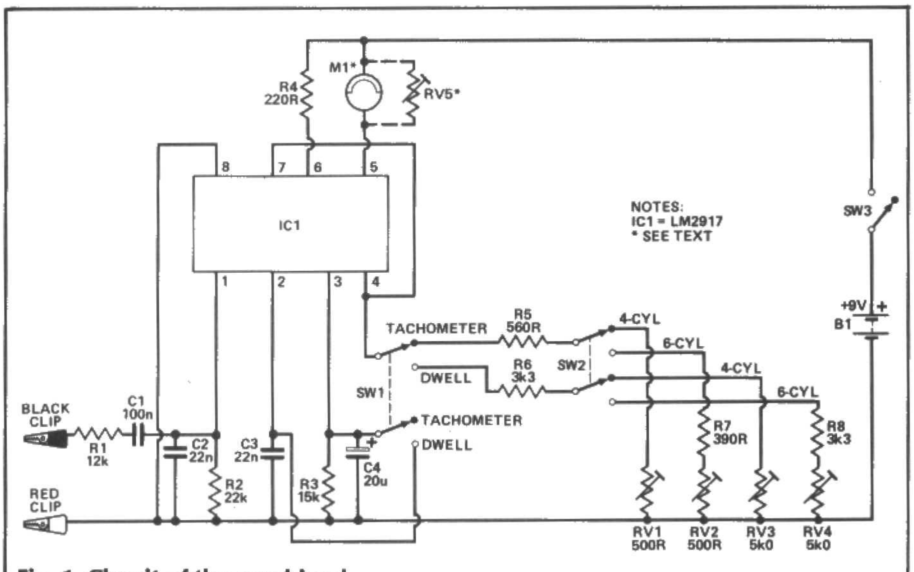


Fig. 1 Circuit of the combined tachometer and dwell meter.

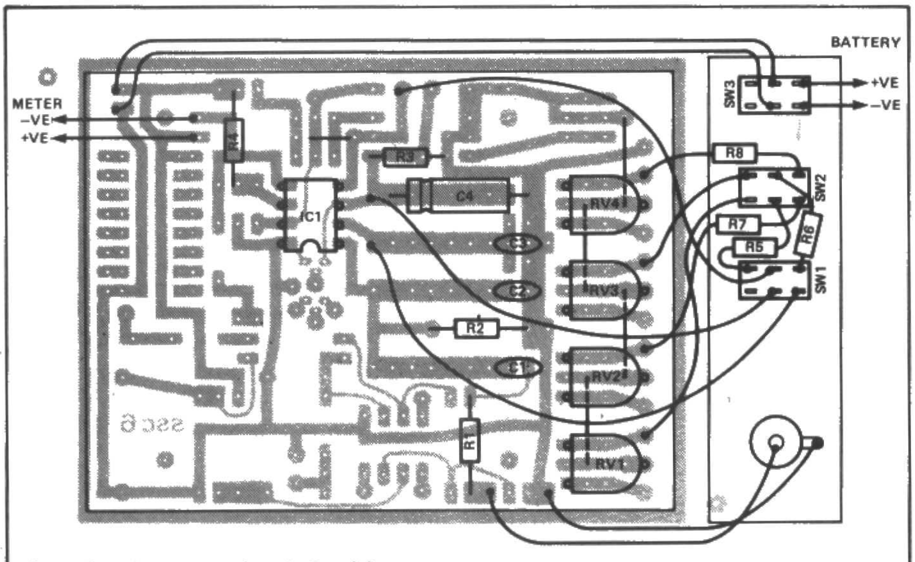


Fig. 2 PCB layout and switch wiring details.

PARTS LIST

RESISTORS (all ¼ W 5%)

R1	12k
R2	22k
R3	15k
R4	220/470R*
R5	560 R**
R6, 8	3k3
R7	390R
R9	12R
RV1	500R**
RV2	500R
RV3, 4	5k0
RV5	200R**

CAPACITORS

C1	100n
C2, 3	22n
C4	20µ elect.

SEMICONDUCTORS

IC1	LM2917N-8
D1*	18V 1W Zener

MISCELLANEOUS

M1	1mA meter movement (or Cirkit type 37-09201 200µA movement — see text)
SW1-3	DPDT miniature toggle switches

PCB; PP3 battery and connector; plug; socket; wire; red and black crocodile clips for test leads; BC3 case; terminals for external meter **.

Calibration circuits**: mains transformer (6V) rectifier mode; 4017 Johnson counter; 10 x IN4148 diodes.

* for use with 12V supply (see text)

** see text

HOW IT WORKS

The tachometer circuit uses the LM2917 in its frequency-to-voltage mode, described in detail in ETI, December 1986, pages 30-33. The novel aspect of this circuit is the dwell meter (fig. 1), where SW1 joins pins 2 and 3 of the IC together.

To see how this affects the IC, imagine that pin 2 is somehow held at half the regulated supply voltage. If the input goes high, current will be dumped from pins 2 and 3, and since pin 2 cannot rise to ¾ Vcc, the currents will continue for as long as the input remains high.

With the input low, pin 3 will continue to source current, but this time pin 2 will sink an equal current. Once again, the current flows will continue for as long as the input remains low.

If pins 2 and 3 are joined — still held at ½Vcc — the net current flow will be twice the pin 2 current when the input is high, and zero when it is low. The average current will therefore be proportional to the percentage of time the input remains high during its cycle.

The dwell meter circuit makes use of this aspect of the IC by developing a voltage across R3 proportional to the average combined current of pins 2 and 3. R 3 is chosen to maintain the voltage at pin 2 between ¼ and ¾ Vcc for the entire range of practical dwell angles.

The input side of the circuit is a simple filter to remove the worst of the electrical noise to be expected from a car ignition system. The output is a variation of the current drive circuit described last month, with presets to trim each range.

of Fig. 3 can be used to provide suitable signals.

With the test leads connected to points B and C (either way around), select the settings for 'tachometer' and '4 cylinders' on the front panel switches. The 100Hz signal represents 3,000 RPM for a 4-cylinder engine, so adjust RV1 to give a reading of 300µA on the meter. Keeping the same input signal, switch to the '6 cylinders' setting and adjust RV2 to give a reading of 200µA, which represents 2,000 RPM.

Select 'dwell' and '4 cylinders' and attach the clips to points A and C (either way round). Adjust RV3 for a reading of 450µA (=45°). Reverse the leads, and make sure that the reading is the same. If it is slightly different (10µA or so), re-adjust RV3 so that the two readings with the clips transposed lie equally on either side of 450µA.

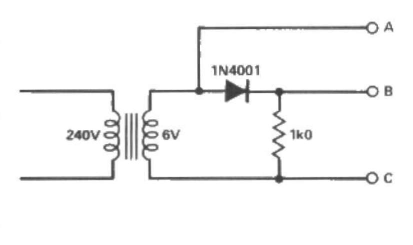


Fig. 3 A simple circuit to provide calibration signals

Switch to '6 cylinders', keeping the same input, and adjust RV4 for a reading of 300μA (=30°). Once again, reverse the leads as a check and adjust RV4 so that the two readings lie evenly on either side of 300μA if there is a slight discrepancy. The calibration is now complete.

If you use a non-linear meter movement, you will have to make your own scale for it. The procedure is quite complicated, but if you follw the steps below exactly, you shouldn't have any problems. The circuit of Fig. 3 cannot be used — you will need a signal generator.

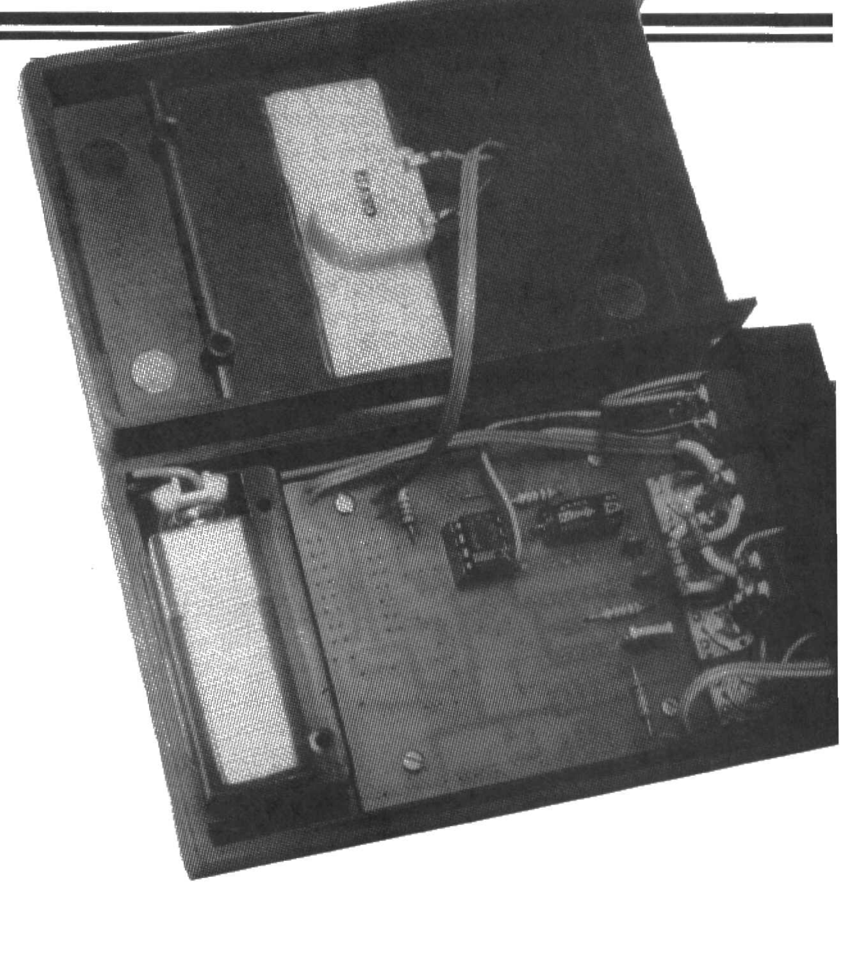
- 1. Set presets RV1-4 to mid position.

- 2. Select 'tachometer' and '4 cylinders'. Apply an input frequency of 300Hz and adjust RV5 (on the back of the meter) until the meter needle deflects almost to the end of the scale. Mark the scale at this point — it represents 9,000 RPM.

- 3. Select '6 cylinders' and increase the input frequency to 450Hz. Adjust RV2 until the needle reaches the mark you made in step 2. If your are successful, go on to step 5. If RV2 has reached the end of its travel and the meter needle will not go high or low enough to meet the mark, go on to step 4.

- 4. Back off RV2 a little, and adjust RV5 to bring the needle to the mark. Select '4 cylinders' again, reduce the input frequency to 300Hz, and adjust RV1 until the needle reaches the mark. Switch back to '6 cylinders' and continue with step 5.

- 5. Mark out the scale at 1,000 RPM intervals as follows: At 400Hz input, mark the needle position as 8,000 RPM; at 350Hz, mark 7,000 RPM, and so on down to 50Hz for 1,000 RPM.



Plenty of room inside, but don't be fooled by the sparsely-populated PCB . . .

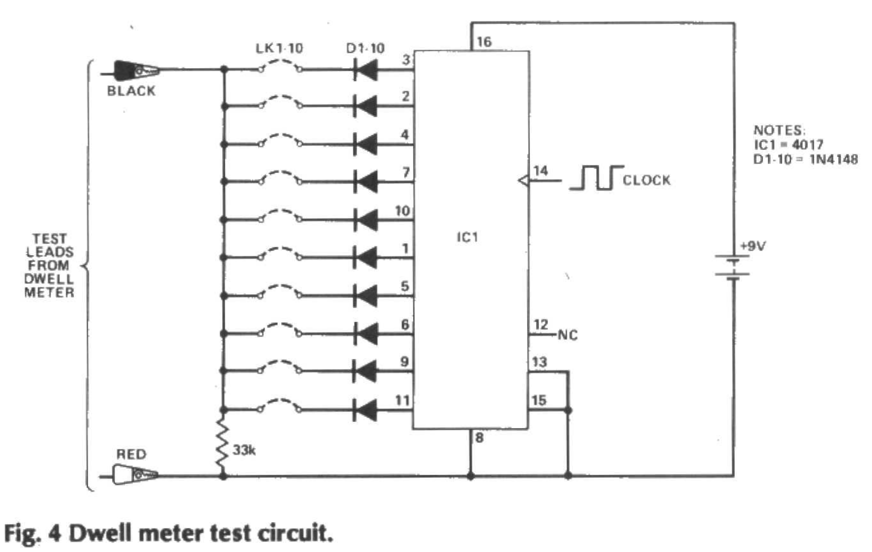


Fig. 4 Dwell meter test circuit.

BUYLINES

The meter movement used in this project was type 37-09201, available from Cirkit, Park Lane, Broxbourne, Herts at £3.81 inclusive of VAT and p&p. The LM2917N-8 IC can be obtained from Technomatic Ltd., 17 Burnley Road, London NW10 1ED for £4.02 inclusive of VAT and p & p. All other parts are readily available from advertisers in ETI. If you have any difficulty obtaining the miniature toggle switches, these are also available from Cirkit, stock no. 53-00201, at 90p each (inc. VAT).

A complete parts set for this project is available from Specialist Semiconductors, Founders House, Redbrook, Monmouth Gwent at £12.90, inclusive (with terminals for external meter) or £16.40 (with meter movement included). They can also supply the BC3 case separately at £3.60.

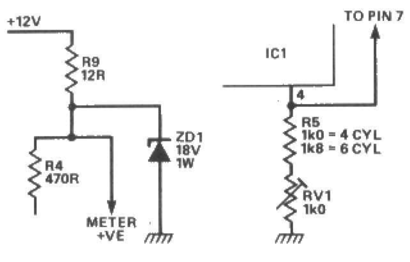


Fig. 5 Modifications to the circuit to allow it to be installed permanently as a car rev counter.

- 6. Switch to '4 cylinders' and check that a 200Hz input shows 6,000 RPM and 100Hz shows 3,000 RPM on the scale. If not, there's nothing for it but to go back to step 2 and try again. If you have carried out all the steps correctly, it will be OK. Interpolations to the scale can be made by selecting intermediate frequencies on the signal generator. For instance, 375Hz (with '6 cylinders' selected) will give the 7,500 RPM mark, and so on.

- 7. Connect up the circuit of Fig. 4 on a breadboard. You can clock the IC from your signal generator; the frequency is not critical — anything around 2kHz will do. Adjust the output level to suit the CMOS power supply.

- 8. Select 'dwell' and '4-cylinders' on the front panel switches. Make links LK1 to LK6 on the test circuit and mark the scale lightly, in pencil, where the needle comes to rest.

- 9. Select '6 cylinders', remove LK5 and LK6 in the test circuit and adjust RV4 until the meter needle reaches the mark you made in step 8. If you are successful, go on to step 11. If RV4 has reached the end of its travel and the needle has still not reached the mark, continue with step 10.

- 10. Back off RV4 slightly. Rub out the first mark, and make a new one at the position where the needle reaches the new mark. Go on to step 11.

- 11. With five links made and five left open, the signal from the test circuit represents a 45° dwell angle on the '4 cylinder' scale. Each removal of a link increases the dwell angle reading by 9°; each addition of an extra link reduces it by 9°, so the scale can be calibrated at 9° intervals. You will not be able to go all the way up to 90° or down to 0°; the range will be roughly 30° to 80°— easily enough to accomodate all the dwell angles you will find, even if the points are very badly adjusted!

With '6 cylinders' selected, five links made and five links open represents 30°. Each removal of a link on this range increases the dwell angle by 6°, and vice-versa, so you can now interleave the scale at 6° intervals. You will find that the combination of calibration in the '4 cylinders' and '6 cylinders' positions will give a scale marked mostly at 3° intervals, with a few points missing. These can be interpolated by eye, or you can use two Johnson counters to give 1.5° resolution, or even three for 1° resolution!

On a positive earth car, connect the red lead to the chassis or to the positive battery terminal; for a negative earth car, connect the black lead to the chassis or the negative battery terminal. If you opt for the chassis connection, be sure the spot you choose is clean so that the contact is made.

On the side of the distributor, you will find a tag which connects to a wire leading to the primary of the ignition coil. Connect the other lead here.

Your car maintenance manual will give the correct settings for dwell angle, idling speed, and so on, and should tell you how to adjust them.

If your car is not fitted with a 'rev counter', you may like to build the meter permenantly into the dashboard. In this case, you can dispense with the switches and just use one calibration control and series resistor (Fig. 5).

To run the circuit from a car battery, you will need to make some minor modifications. R4 must be increased to 470R and a resistor and zener must be added, as shown in Fig. 5, to protect the IC from destructive transients on the car's electrical system.

The PCB

It will not have escaped your notice that the PCB for this project has rather a lot of extra holes and spare space. The PCB was designed as a general purpose board for LM2917 circuits. It will support all the different configurations mentioned in the article 'The Next Great Little IC' (ETI December 1986), and can be used as a breadboard for circuit ideas or to build complete circuits, as in this project.

ETI

TECH TIPS

Priority Selector

Paul Harding
Exeter

The circuit shown here indicates which of its inputs was active first since it was last RESET. It is ideal for use as a quiz monitor.

In the circuit's quiescent state, following a RESET pulse, the outputs of IC1c and d are high. since the inputs to both IC1a and b are all high, their outputs are low, and the initial condition is maintained.

Taking, say, INPUT 1 low causes IC1a's output to swing high, and IC1c's output to swing low. This signal is fed back to latch the original input, and hence output, signal.

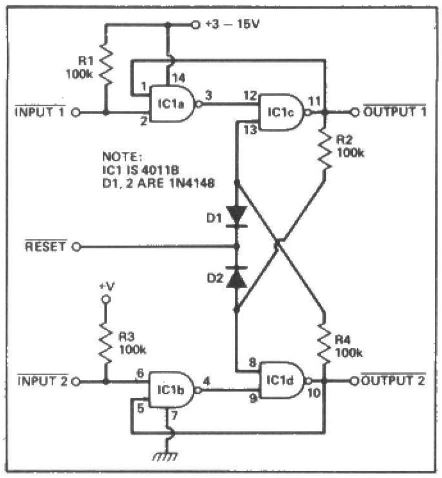
IC1c's output is also coupled to one of IC1d's inputs via R2, clamping the latter's output high, regardless of the subsequent status of INPUT 2. Circuit operation is similar in the event of INPUT 2 going low prior to INPUT 1, following a RESET pulse.

Incidentally, from the above description it can be seen that although IC1c and d are drawn in the classic flip flop configuration, it is either IC1a and c or IC1b and d that actually perform the latch function.

Taking RESET low will forward bias either D1 or D2, forcing the active output of the circuit to swing high. R2 and R4 prevent large currents from flowing from IC1c or d during this time. Decreasing R2 and R4 will reduce the time taken for the circuit to lock out subsequent activity on the initially inactive input, at the expense of increased current through the RESET input.

With the values shown, and using published data for gate input capacitance (5p–8p), there is an additional 400–600ns delay when compared with R2 and R4 at their minimum value of 1k0.

Finally, if it is desired to construct a positive, rather than negative logic circuit, this can be implemented by using NOR gates for IC1 (for example, the 4001B), taking the pull up resistors R1 and R3 to ground, and reversing D1 and D2.



Computer Control Of AC Power

Max Tykesson,
Denmark

This circuit allows a home computer to control heavy AC loads such as heaters from zero to full power. With the triac shown and good heatsinking and cooling arrangements, the maximum load is 3.5kW.

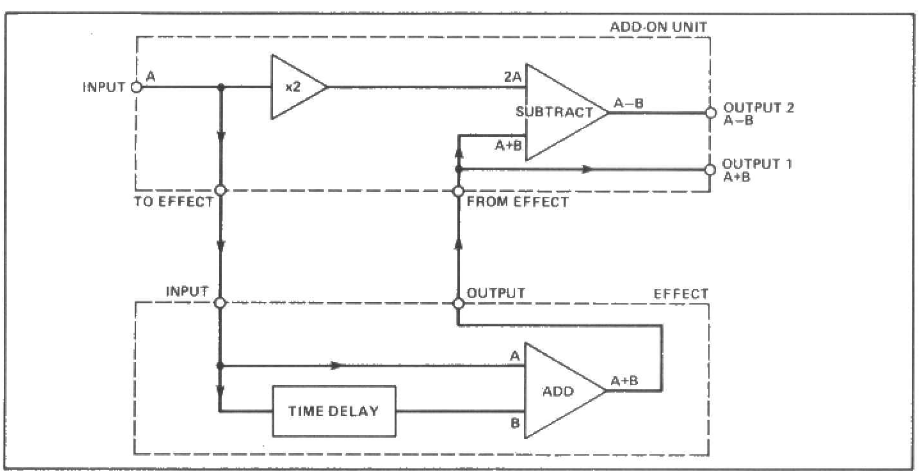
Working from left to right across the circuit diagram, the first section is the 8-bit parallel input from the computer. Each input line is fed to an opto-isolator which provides mains isolation and then to a NAND Schmitt trigger (ICs 9 and 10). These ensure clean switching of the signal between logic states. The digital signal is converted to an analogue signal by means of the R-2R ladder, built around resistances R25-41 and then buffered by IC11 to provide a low impedance drive for the triggering circuit, IC12. This IC is designed as a general purpose triggering unit and is connected here as a full-wave AC controller. It takes its power directly from the mains and derives its own Vcc rail to drive the internal circuitry. This rail is available at pin 11 and is used here to drive the other ICs, thus removing the need for a separate mains power supply.

Stereo For Time Delay Effects

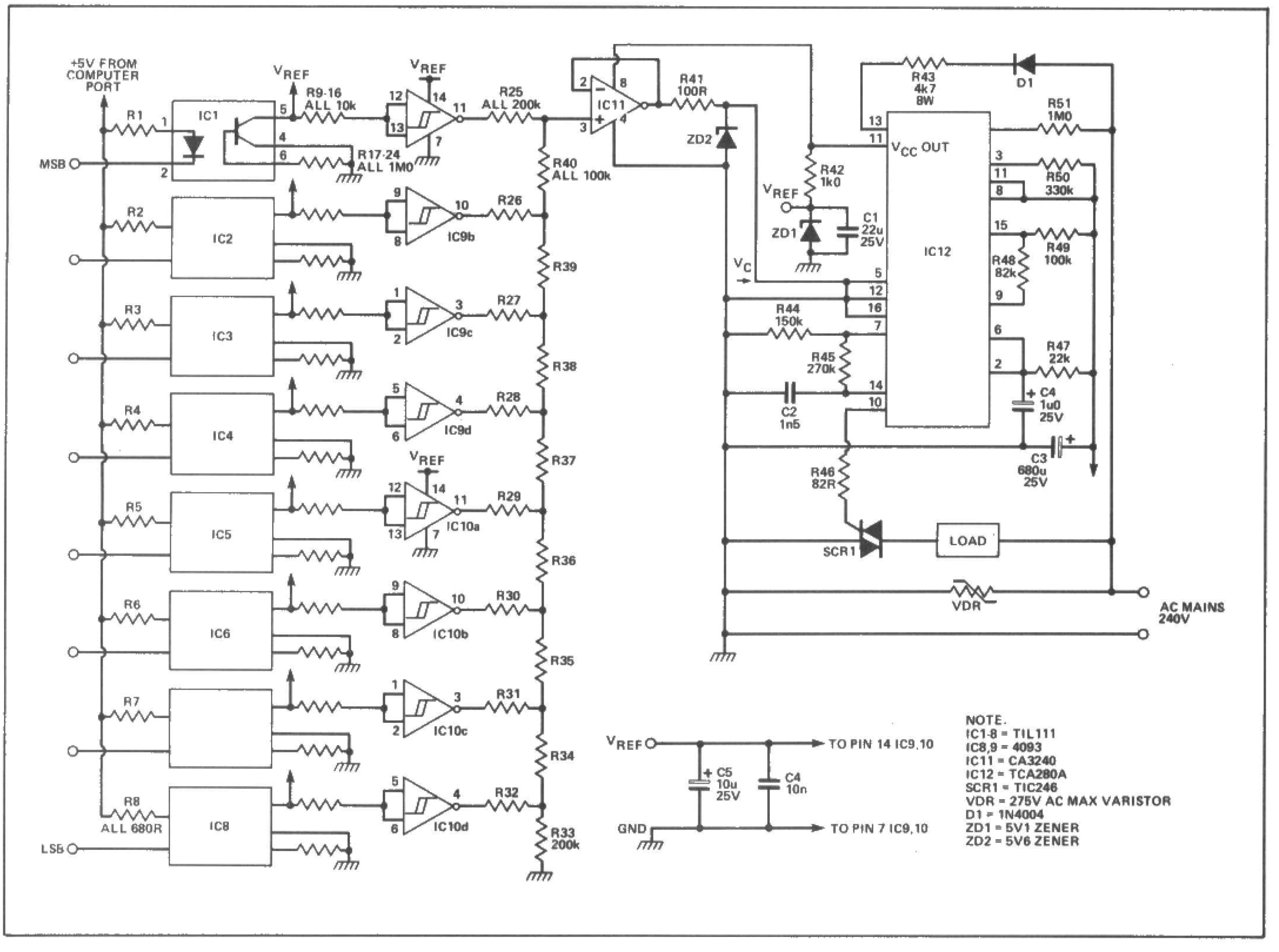
Marcus Valentine,
Bristol.

This little circuit will give a pseudo stereo effect when used in conjunction with any effects unit which incorporates a short time delay, for example, flanger, chorus, vibrato, etc. Some manufacturers do produce effects with stereo outputs but they usually use this as an excuse to bump up the price by several tens of pounds. This device can be built for a night's beer money.

Effects of this type work by mixing the output of the time delay circuit with the input. This results in the cancellation of some frequencies due to some of the frequency components of the delayed signal being 180° out of phase with the input. This produces the characteristic notched frequency response.



If we refer to the input signal to the effects unit as A and the signal appearing at the output of the time delay circuitry as B, the output signal from the effect will be A+B. One way of producing an additional



pseudo-stereo output is to subtract the delayed signal from the input signal to give A-B. This can be done with a single op-amp. This is all well and good, but the B signal is safely tucked away inside the effect concerned. With this circuit it is possible to obtain the B signal without butchering your favourite and comparatively expensive effect.

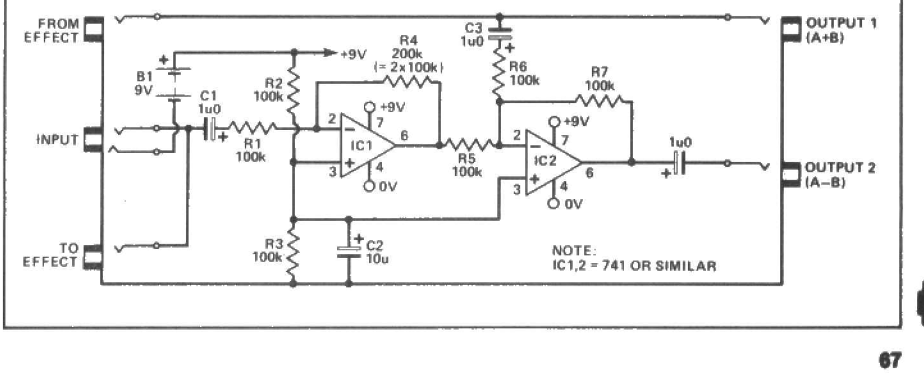
Referring to the block diagram, if we take twice the input, that is 2A, and then subtract the output, A+B, we will have 2A−(A+B)=A−B, which is what we are after for the other output.

The next thing to consider is what happens when the effect is switched-out. In this case, its output will obviously be the same as its input, A, so the add-on circuit receives A at both its inputs. Its output is therefore 2A−A=A. This is very convenient as it means that the effects in/out switch will still function correctly. When the effect is switched out the input appears unchanged at both outputs.

The final circuit can easily be derived from the block diagram. The A signal is actually multiplied by −2, but this is cancelled out in the second op-amp where the A+B signal is added to the −2A signal and sum inverted to give −(−2A+(A+B)) which is A−B.

The circuit can easily be built on a piece of veroboard and mounted in a small diecast or aluminium box. It will run quite happily on a small 9V battery. The stereo input socket is used to disconnect the battery when an input plug is not present.

In use, the add-on unit is placed in the signal path instead of the effect, and the effect is plugged into the add-on unit.



Phone Line Monitor

Steve Terry
Eastbourne

This circuit, when connected to a telephone line equipment with new-style sockets, will switch a relay whenever the phone is ringing, or when the phone is off the hook. It was originally designed to mute a hi-fi so that the telephone could be used, but could be adapted to other uses.

IC1 is a high sensitivity dual opto-isolator. Its inputs are connected to the telephone line via current limiting resistors R1 and R2. The bridge rectifiers ensure that the polarity of the line is unimportant, and that the AC ringing signal is detected correctly.

R1 and BR1 form a ring detection network, and this turns on the output at pin 7 of the opto-isolator. R2 and BR2 detect when the phone is on the hook, the value of R2 being chosen so that the output at pin 6 does not turn on until the line voltage is greater than about 30 volts.

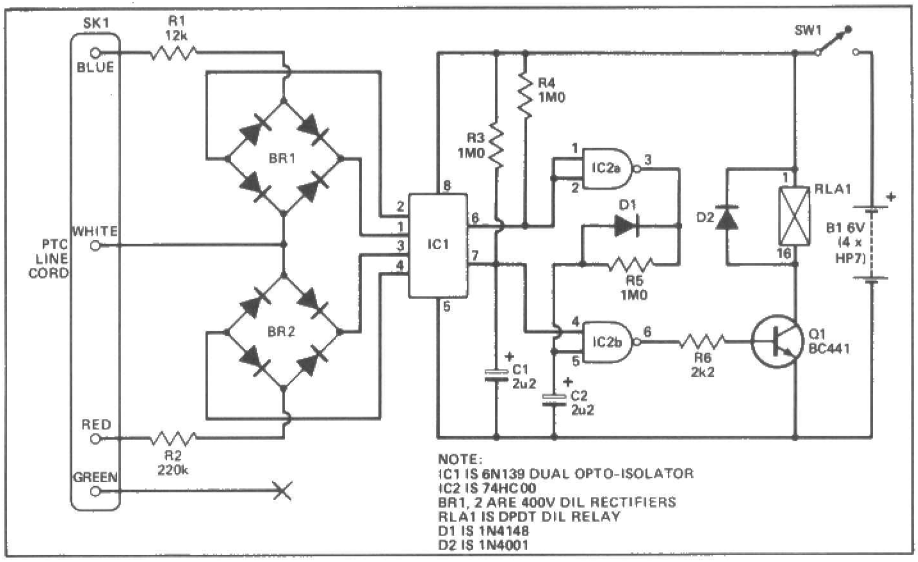
The outputs of the opto-isolator are open collector transistors. Thus, R3 and C1 ensure that pauses in the ringing signal do not cause faulty operation of the circuit.

IC2a inverts the on hook signal, and passes it via the time delay network D1, R5, C2 to the input of IC2b. This time delay ensures that the circuit responds quickly to the off hook condition, but slowly to the on hook condition. Therefore, dialling pulses are ignored, and the output remains active.

Finally, the output of IC2b is high when either of its two inputs are low, and this energizes the output relay via Q1.

The circuit is powered by a 6V battery. The current consumption is very low when the circuit is in the stand-by state, and is about 100mA in the energized state. This won't be a problem unless you intend to be on the phone for hours on end, and if you are then the cost of new batteries will be far outweighed by your phone bill!

A switch should be included in the power line, as the relay will switch if the circuit is disconnected from the phone line when switched on. A mains power supply should *not* be used, since 240V can do a lot of damage to the phone system if it reaches the wrong place. Similarly, the output relay should not be used to switch mains. The type specified is rated at 1A/30V.



No connections to the relay contacts are shown, this depending on the use to which the circuit is put. The contacts are double pole, double throw, and they are completely isolated from both the circuit and the telephone line.

Improved Missing Pulse Detector

Trevor P. Hopkins,
Manchester.

A recent project required a 'missing pulse' detector. If a pulse was not received within a preset time interval, an alarm would be sounded. Numerous data books give the circuit shown in Fig. 1, which utilises the ubiquitous 555 timer, configured as a monostable.

This circuit has an external PNP transistor Q_1, which discharges the timing capacitor C_T when an input pulse is received, thereby restarting the timing interval. The wait time, within which a pulse must be received, is given in the data book as $1.1\ R_TC_T$.

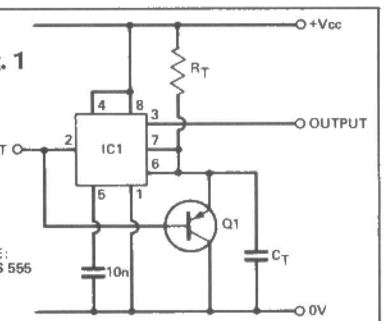
This circuit has a number of limitations. In particular, the input pulse must swing very close to the negative supply rail in order to turn transistor Q_1 on, even though the 555 timer will be triggered by pulses of much smaller amplitude. This caused very unreliable operation in my application. In order to provide a missing-pulse detector with greater sensitivity and reliability, the circuit of Fig. 2 was developed.

The improved missing-pulse detector uses two external transistors to discharge the timing capacitor. The input voltage need only swing down to about ⅓ of the power supply voltage in order to retrigger the circuit.

Note that a small resistor is placed in the collector of Q_2, in order to reduce the peak collector current when discharging C_T. This is probably only necessary when large values are used for C_T.

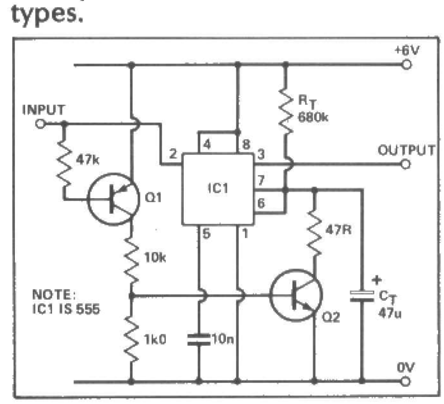
This circuit has been tested with both the low-power CMOS

Fig. 1



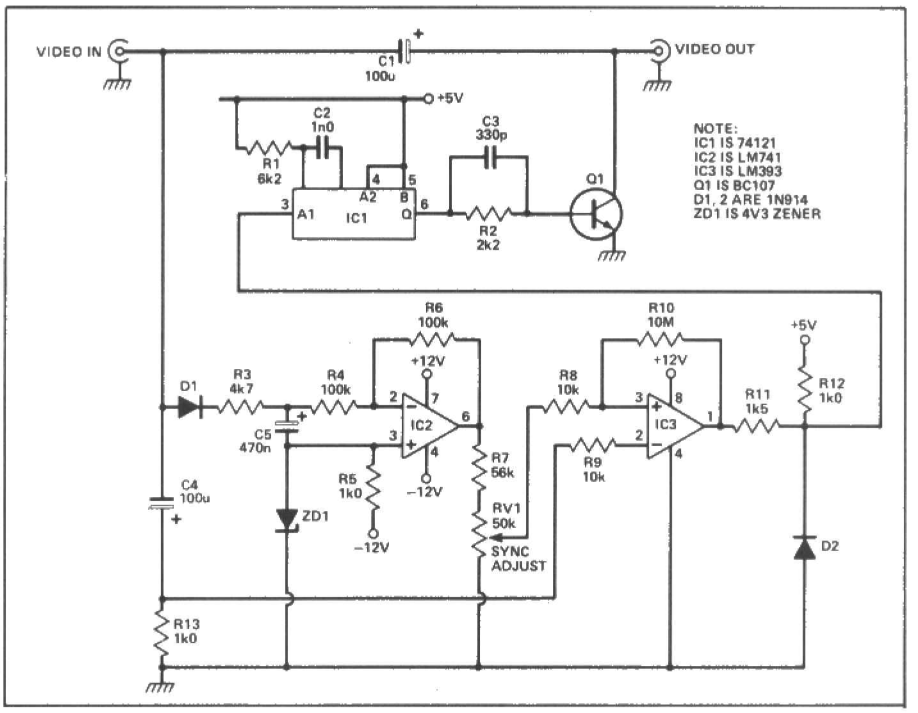
(ICM7555) and low-power bipolar (TLC555C) types, as well as the standard power (NE555V) timers. The values shown in Fig. 2 give a timing period of about 35 seconds. In many cases, the 10n capacitor may be omitted.

Transistors Q_1 and Q_2 may be any small-signal PNP and NPN silicon devices. ZTX212 and ZTX108 types were used in the prototypes. These are equivalent to BC212 and BC108 types.



Video Clamping Circuit

**L. Robertson,
Aberdeen.**



The need for this circuit arose when the video signal to be used was unstable and drifted enough to cause a loss of sync. The problem was rectified thus:

The diode D1, the 4k7 resistor and the 470n capacitor give a voltage level to the inverting input of the 741. The non-inverting input is referenced to –4.3V to allow for negative signals.

Part of the 741 output is tapped off and goes to the LM393 comparator, the inverting input of which is fed by the video signal via the 100μ capacitor.

The 50k potentiometer is set so that the non-inverting input of the LM393 is sitting approximately midway up the sync pulse level on the inverting input.

As the video input signal varies then the two inputs to the comparator vary also giving no charge to the pulses at the output, which are clamped between the 0V and +5V.

These pulses are used to trigger a monostable with an output duration of 4μs on the negative edge of the sync pulse so that the Q output of the 74121 monostable is a pulse 4μs wide coinciding with the back porch part of the video signal.

This is then used to switch the transistor so that it conducts on every pulse pulling the collector down to 0V. The black level of the video is thus clamped at 0V despite any variations in input level.

ETI

IN-CAR CIRCUITS

Some TECH TIPS for car owners, devised by Andrew Armstrong.

Bargraph Fuel Gauge

This circuit gives a bargraph display of the level of fuel in the tank without affecting the operation of the normal fuel gauge. The display circuitry is a little uncommon.

Display

As can be seen from inspection of the circuit, the display does more than the LM3914 bargraph IC on its own would do. The major disadvantage of this type of IC is that display resolution is limited to ten steps. Two modifications improve useful resolution.

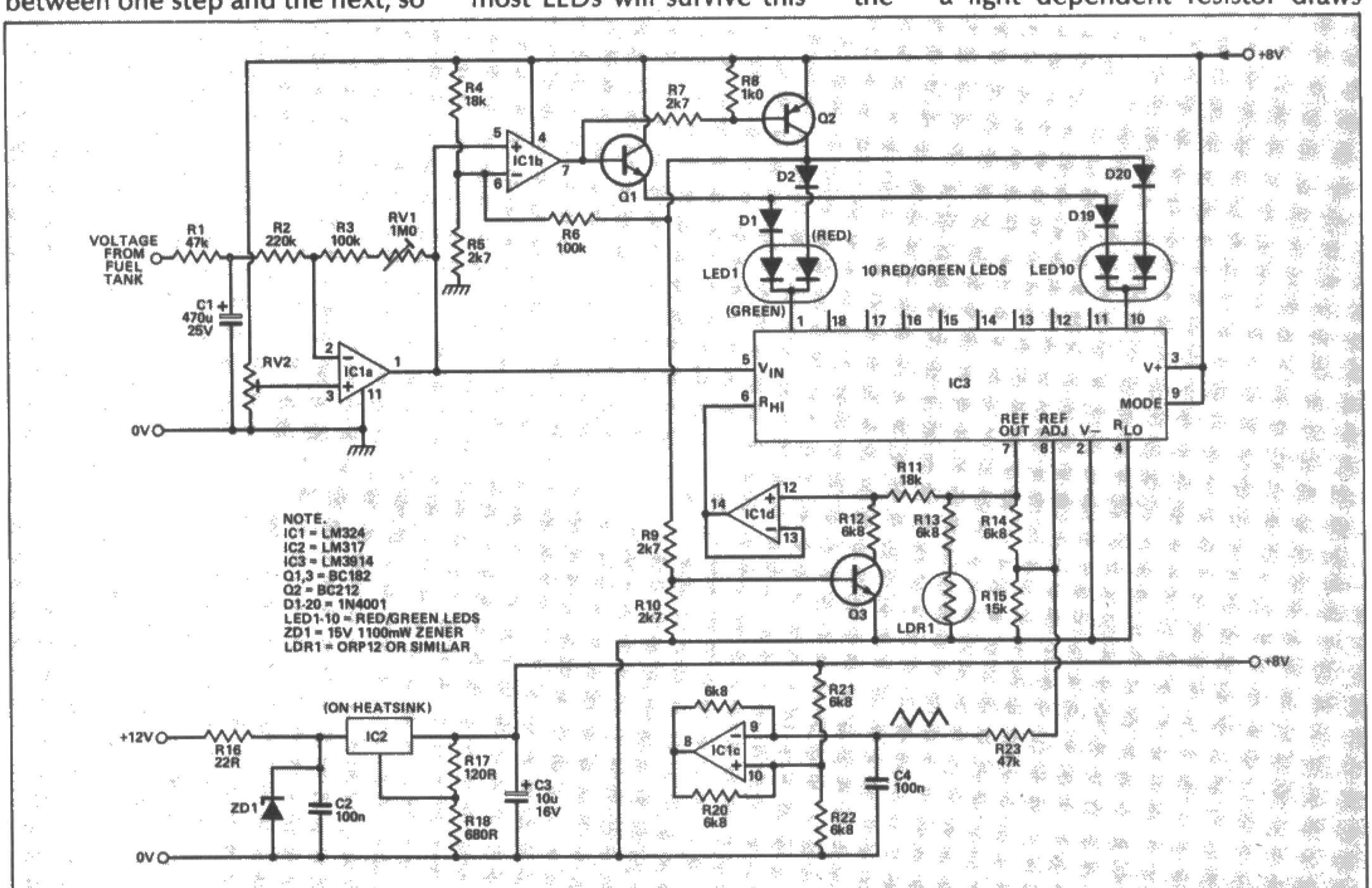
First of all, a triangular signal (produced by IC1c and associated circuitry) is added into the reference voltage via the reference adjust pin. This has the effect of mark/space ratio modulating the transitions between one step and the next, so that one step appears to fade into the next. In this way it is possible to judge to closer than half a step. The amount of fading between steps is determined by R23, so if you prefer to have more or less fade, the resistor value may be changed as appropriate.

To increase the resolution on low readings, the range is automatically switched. IC1b is connected as a comparator with a small amount of hysteresis. It switches when fuel is low and the output signal falls below about 1V. When it does so, the colour of the display changes from green to red. Q1 is switched off, and Q2 is switched on, feeding power via the diodes to the red LEDs.

The LEDs receive their power via individual diodes because most LEDs are not rated to withstand much reverse voltage, and the LEDs which are switched off could experience about 6V reverse. In practice, most LEDs will survive this — the diodes are only a precaution.

When the display colour switches, the reference voltage is also switched. For low range, Q3 switches on and pots down the reference from 5V to about 1.2V. Changing R12 will alter the low range reference if experiments suggest that it should be different, but the values shown give a good starting point. Similarly, the switching point at which the display range changes can be altered by changing R4, R5 and R6. Clearly, the switching point and the low range reference voltage should match up, ideally so that the display switches to high range just after the tenth green LED switches on.

One extra refinement is that the display dims at night and brightens in daylight. The LM3914 has the useful property that the LED current is proportional to the current drawn from the reference pin. In this design a light dependent resistor draws



extra current in daylight to brighten the display. Even then, the current available from the LM3914 is so low that some effort needs to be made to shield the display from direct light. A good solution is to fit a circularly polarised (not coloured) display filter in front of it.

The voltage regulator is set to provide adequate voltage to operate the system, while keeping down the dissipation in the LM3914 when all the LEDs are on. The maximum LED current is calculated to be just inside the chip's capabilities even when they are all switched on at maximum brightness.

Input Circuit

The circuit of the normal fuel gauge is shown in the instrument voltage regulator project. From this it can be seen that the average voltage at the junction between the tank unit and the gauge will depend on the fuel level, and it is this which we measure.

Because of the way in which the instrument voltage regulator works (unless you build the electronic version) the voltage at this point is in the form of a square wave, which is averaged by the thermal time constant of the bimetallic fuel gauge.

To achieve a similar effect to the bimetal strip, there is a resistor and a capacitor at the input of the bargraph gauge. A higher voltage capacitor is used to minimize the leakage current, and hence the error, in this part of the circuit.

The voltage is lower when the fuel level is higher, and vice versa, so the input stage of the circuit is an inverter. The voltage never averages to zero, but varies about a few volts positive according to the fuel level. The offset of the inverter is adjustable to take account of this fact. The gain is also adjustable so that the range can be set accurately.

Unfortunately the adjustments are interactive, so an iterative adjustment procedure is necessary. RV1 should be adjusted to obtain the correct maximum reading, and RV2 for the correct zero, and the sequence repeated until it is accurate. If the tank unit is accessible this can be done quickly by holding the float in the full and empty positions while the adjustment takes place. Otherwise, I am afraid, it will have to be set over several fillings and emptyings of the tank. Because the ordinary fuel gauge continues to work this should cause little problem.

Thief Staller

This is an anti-theft device with a difference. Its purpose is to convince your neighbourhood 'tea leaf' that the car he is trying to steal isn't much good, and that it just is not worth pinching. The thief can start the engine, but when he revs it up it coughs and dies. It can only be run once the owner has switched off the thief-proofing gadget.

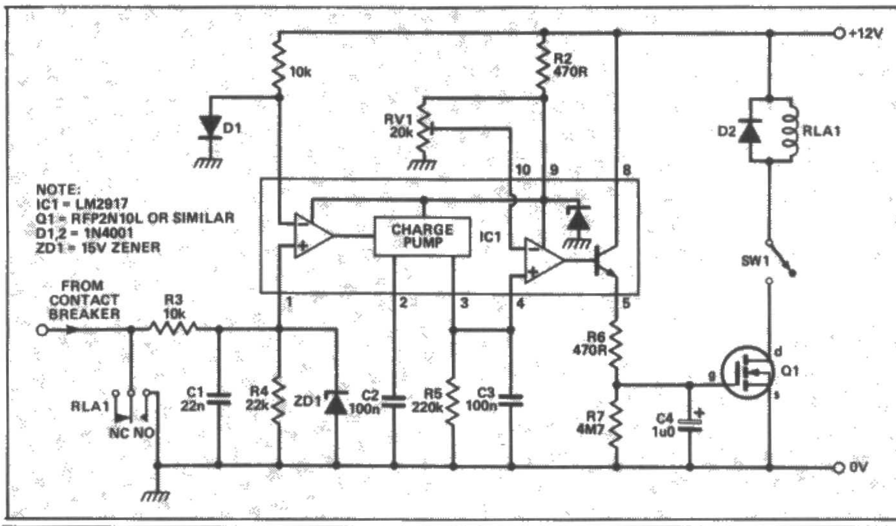
The LM2917 frequency to voltage converter is used (again). This IC has a zener diode built in, so there is no need for complicated power supplies. The input stage of this circuit is similar to that of the tachometer project in this issue.

On each input cycle, C2 is charged to a set voltage and the charge is transferred to C3. The voltage on C3 does not rise indefinitely, but stabilises at the point where the discharge current through R4 is equal to the average current due to the transfer of charge. This increases with RPM.

The output op-amp of the LM2917 is wired as a comparator which will switch when the RPM exceeds a preset figure, set by RV1. When the output switches, C4 is charged, with R5 limiting the charging current to protect the LM2917 output stage.

While the capacitor remains charged, the FET Q1 is switched on and the relay is energised, shorting out the contact breaker. The engine stops, and can be restarted about five seconds later when C4 has discharged via R7. After a few tries most people should give up.

The device should be installed near the distributor or coil, and concealed as well as possible. The switch should be mounted somewhere under the dashboard out of sight. The speed at which the circuit operates should be set to about 1500 RPM by adjusting RV1.



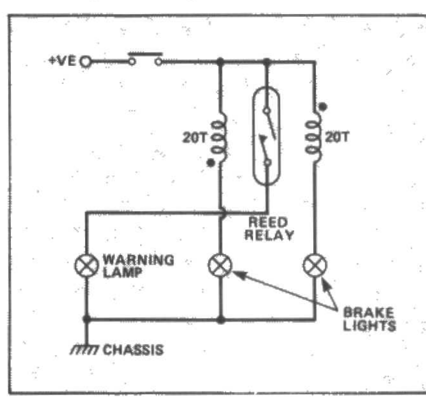
Brake Light Failure Indicator

This is a simple gadget to detect the failure of one brake light. It works on the principle that the current through each bulb is the same, so that the magnetic field generated by the current in each coil cancels with the other one.

If one fails, there is a substantial field which switches on the reed relay and illuminates the warning lamp for as long as the brake pedal is pressed. If both fail, of course, nothing happens.

Some experimentation is necessary with the number of turns required. This will depend on the particular reed relay chosen, but almost any type of reed will do. If the relay closes even when both lamps are working, then there are probably too many turns, or else the coils are not close enough in turns to cancel the magnetic fields accurately.

Experimenters with a penchant for semiconductors could use one of the Hall effect switches available from Electromail, but a reed relay works perfectly well.



Aerial Without Holes

Here is a method of using the rear window demister as an aerial for radio reception. The basic technique works well for long and medium wave reception, as proved by several friends' cars on which it is used. This design is extended to give improved reception of VHF transmission.

Normally, any radio signal picked up by the rear window demister would be shorted promptly to ground, where one side of the demister elment is connected. When the power is switched on, the other side is connected to ground as far as RF is concerned, so there is no chance of tapping off any signal. If the element were disconnected at both ends, though, it could be made to work as an aerial.

In this design, it is disconnected from the point of view of the RF, but the power is still connected. L1 is a bifilar wound air-cored coil which presents a high impedance to VHF signals, preventing them from leaking to ground.

L3 is a bifilar coil wound on a pot core, and is of a high enough inductance to present a high impedance even to longwave signals. Because of its core material it would be lossy at VHF, and would leak such signals to ground, which is why L1 is needed.

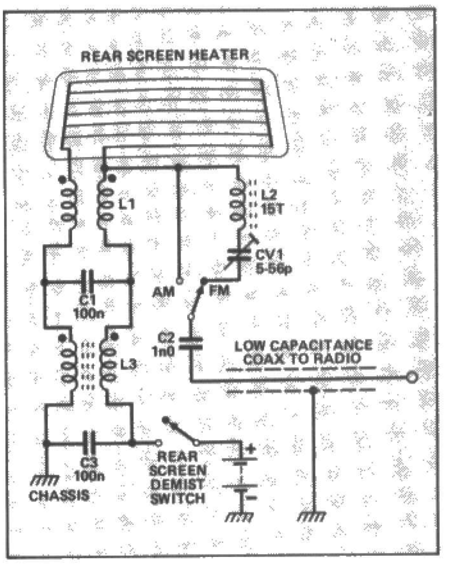
L3 in particular, must be bifilar wound so that the magnetic fields generated by the forward and reverse current flow in the element cancel out. Otherwise the magnetic material would saturate, and lower the inductance of L3 almost to that of an air-cored coil.

Even with L1, VHF reception might leave something to be desired, because the matching of the heater element into the radio is rather worse than with a conventional aerial. L2 and CV1 provide crude tuning and impedance matching to improve the situation.

To make the bifilar coils, two strands of enamelled copper wire should be twisted together. If possible, a wire diameter of about 0.5mm should be used to prevent excessive heating of the coils. L3 should consist of 20 turns wound on almost any reasonably substantial pot core. An RM10 type would be suitable. L1 should be 20 turns wound on a thick pen or any object about ½-inch in diameter.

L2 and C2 require some experiment. A good starting point for L2 would be 15 turns of 0.25mm wire on a ¼-inch former fitted with a VHF tuning slug. The turns may be increased or decreased if the capacitor needs to be set to one end of its range for best reception. If maximum capacitance is needed then increase the inductance, and vice versa.

When the unit is built, it should be connected to the radio using a special low capacitance screened lead intended for use with car aerials.



Replacement Voltage Regulator

In older cars, especially, the instrument voltage regulator is likely to have rather burned contacts. This means that it will gradually become intermittent in its functioning, and will generate inordinate amounts of car radio interference meanwhile. The sound of this particular interference is often reminiscent of feet on gravel.

Figure 1 shows the normal type of instrument voltage regulation found in, for example, old Marinas. Heat bends the bimetallic strip away from the contact, which turns off the power to the instruments and to the small heating element.

The strip cools down, and switches the power back on. The action maintains the same average heat and hence the same average voltage, regardless of the exact input voltage.

Figure 2 shows a typical instrument. The bimetallic strip here has a long thermal time constant, so it only responds to the average current through it and ignores the fact that the power is switched on and off. It will work just as well with a steady voltage, if that can be provided.

Figure 3 shows a means of determining what steady voltage is needed. Once this circuit is connected it should be left until the meter reading is more or less steady, then the reading should be noted. The voltage is normally about 10V.

The old regulator should then be prised apart and the old works removed from the terminals. The new circuit shown in Fig. 4 should then be constructed on the remains, and set to the voltage measured in Fig. 3. The new regulator can now be plugged in. All should work well.

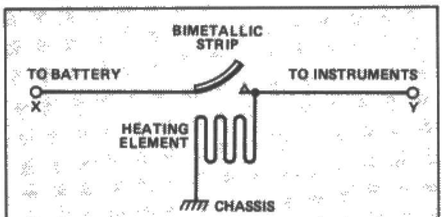


Fig. 1 Usual bimetallic strip regulator.

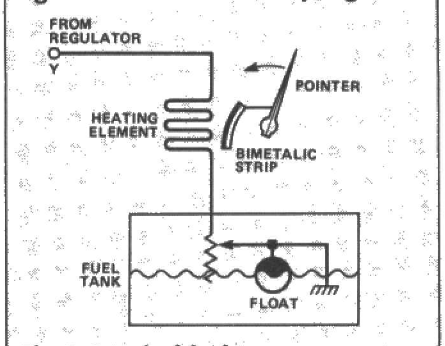


Fig. 2 A typical fuel gauge.

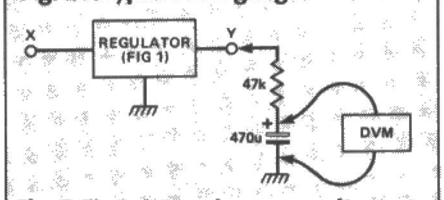


Fig. 3 First determine your voltage.

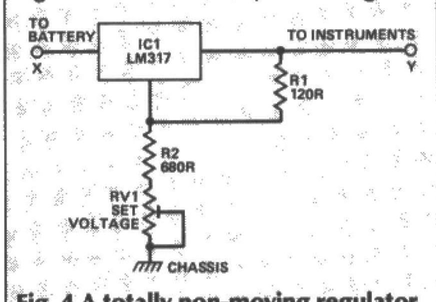
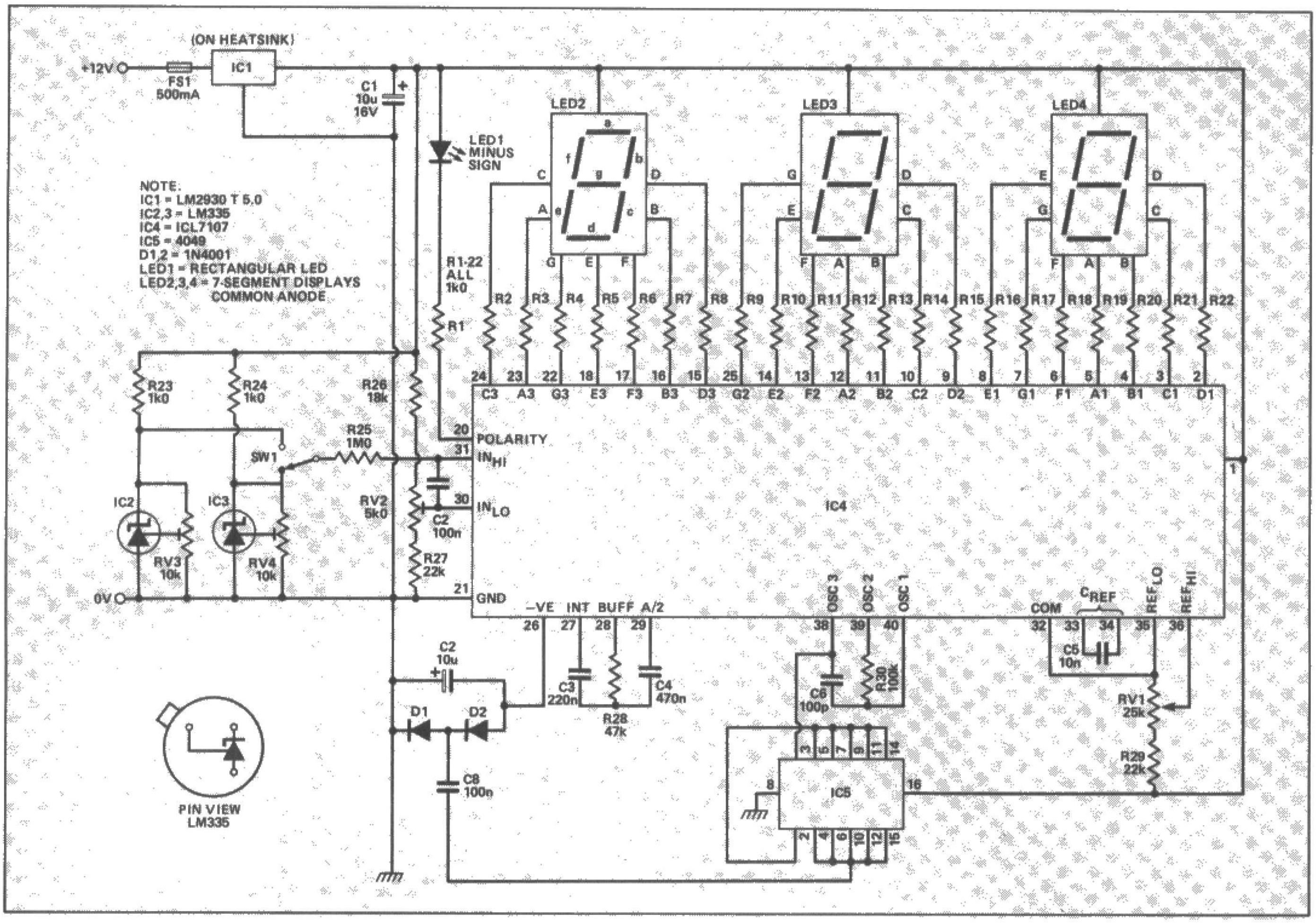


Fig. 4 A totally non-moving regulator.



Digital Temperature Readout

Here is an accurate digital thermometer which can measure the temperature both outside and inside the car. It uses a standard Intersil LED DVM IC which is widely available. Among other things, it can warn of the danger of icy roads.

This DVM chip, in common with all or most others, requires a split rail supply to operate. This supply is provided by a diode pump circuit driven from the on-chip oscillator via a 4049 CMOS buffer. As long as the power supplies are correct, the display will read out the difference in voltage between IN HI and IN LO as a proportion of 2Vref. The 7107 is a 3½-digit converter, so the three digits actually used will work over a range equal to Vref (minus one least significant digit).

Reference

The temperature sensors give an output of nominally 10mV/K, which is 10mV/°C relative to 2.73V. Therefore, the least significant digit of the display will read tenths of a degree if it has a step size of 1mV. This makes the maximum reading 999 mV, which means that 1V reference voltage is needed. The initial accuracy is only ±6°C, however, so individual calibration pots are needed for the interior and exterior sensors.

The power supply regulator is a 5V device intended for automotive use. It is supposed to be immune to damage by the substantial voltage spikes which can be present on car electrical systems. A 7805 would also be suitable but it is not guaranteed to be proof against the worst that a car electrical system can offer. Operating on this low voltage, the dissipation of the display current limiting resistors is minimal and resistor networks may be used if this is convenient.

Adjustment

To obtain best performance from this circuit the pots should be adjusted in the correct order. First the reference voltage should be set to 1V using RV1. Then the voltage on the IN LO input, pin 30, should be set to 2.73V above ground using RV2. Then, with the aid of an accurate thermometer, the temperature sensors should be calibrated, using RV3 and RV4.

Finally, the exterior temperature sensor should be positioned somewhere outside the car, not near to the engine or exhaust. If there is a convenient cable run from the dashboard to the engine compartment the sensor wires can be routed through this way, but the sensor should be positioned clear of the engine, and preferably level with the sills behind the front wheel. This should give warning if the road is likely to be icy.

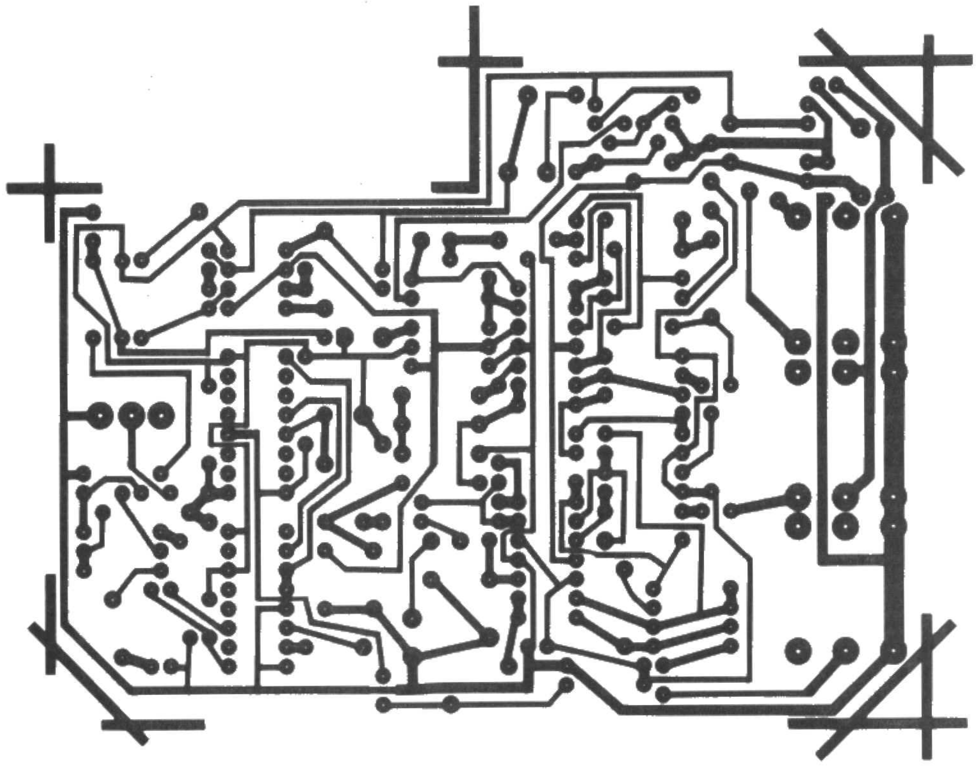
If the unit is impossible to calibrate, then check that the negative supply is at least 1.5 volts negative with respect to ground. If it is not then check all the components in the negative supply circuit (D1, D2, C2, C8 and IC5).

The only other likely problem is that the displays may be wired incorrectly, which should be obvious because the read-outs will only resemble numbers by sheer chance if the connections are wrong.

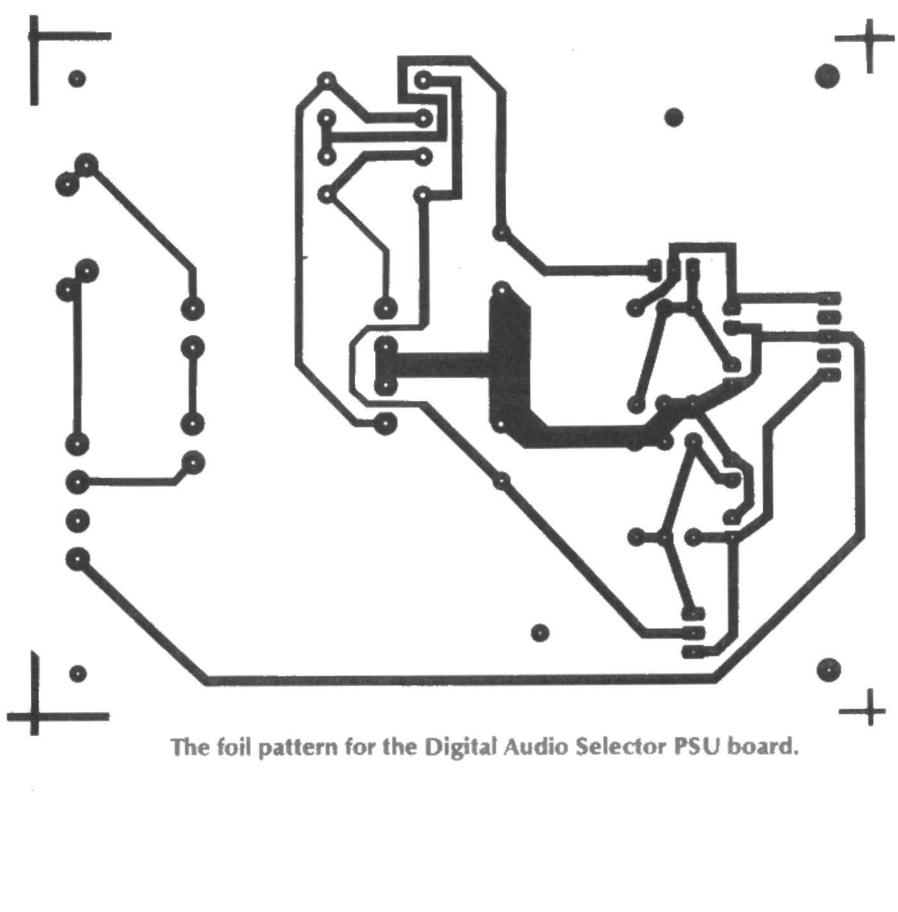
ETI

Our readers' survey — the results of which are just coming through — suggests that you'd like more of these short circuits. Keep a look out for more next month.

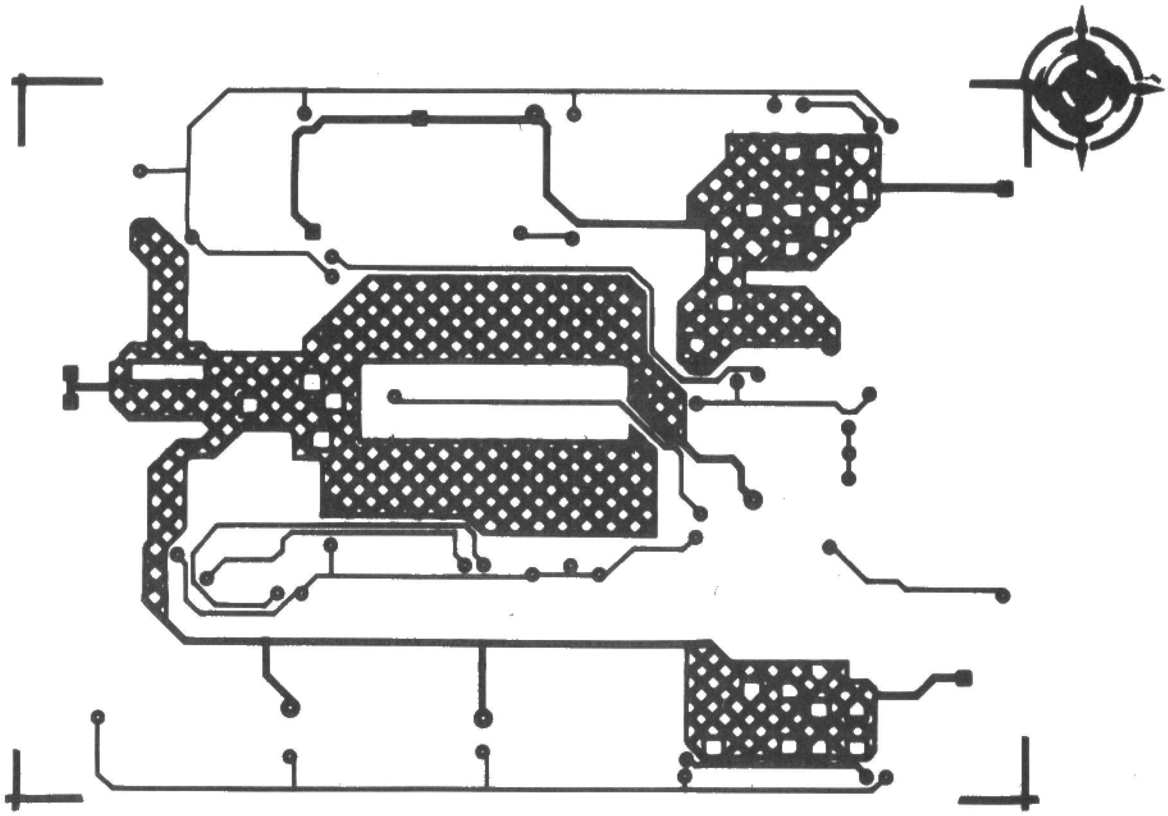
PCB FOIL PATTERNS



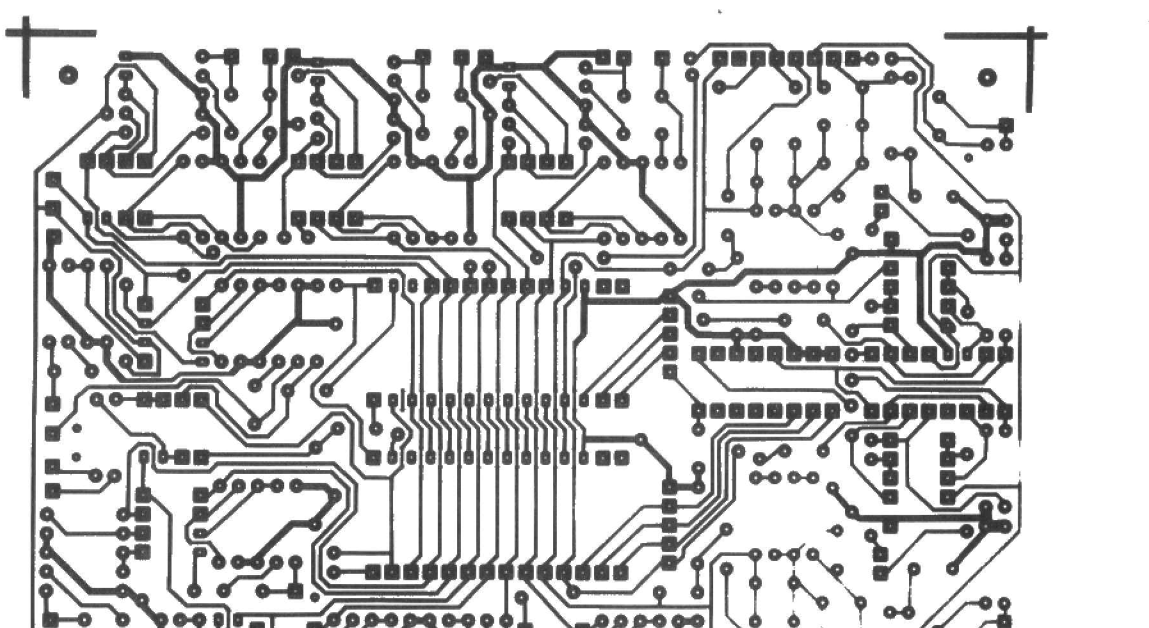
The Flanger foil pattern.

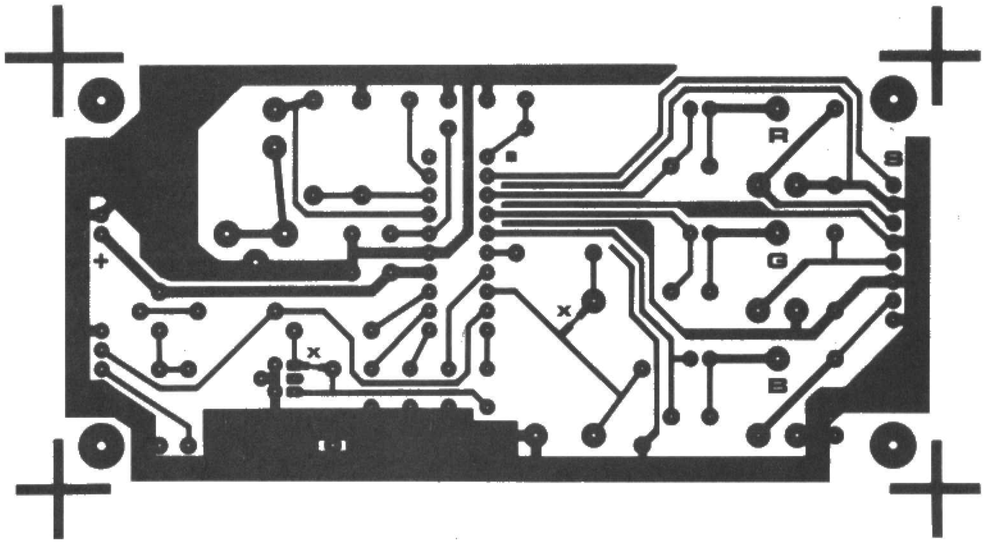


The foil pattern for the Digital Audio Selector PSU board.

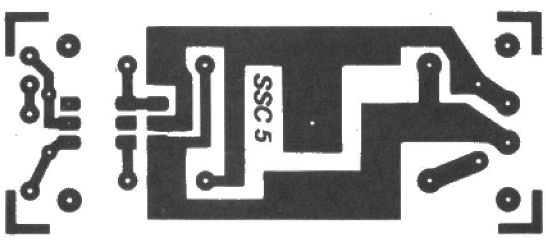


The top and bottom foils for the Digital Audio Selector audio board.

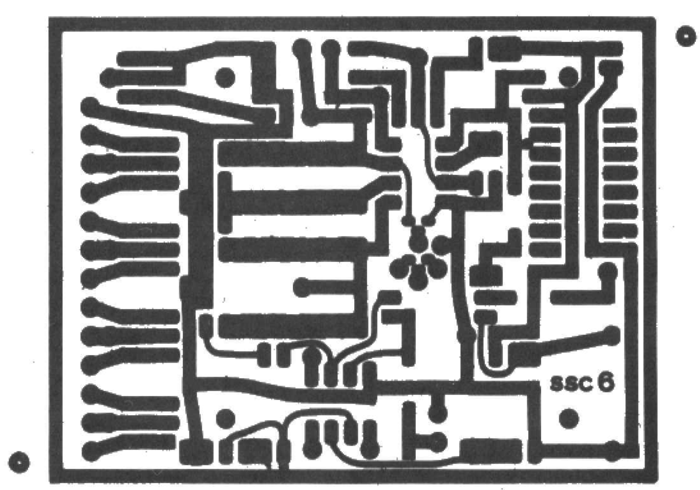




The foil pattern for the RGB Converter board.



The Mains Controller board foil pattern.



The multi-purpose LM2917 board which is used for the Tacho/Dwell meter.

Due to lack of space, the foil pattern for the LEDscope board have been held over until next month.

ETI

ALF'S PUZZLE

Alf has been attending evening classes at the local technical college again. After a few hours of what he thought was extremely advanced abstract network theory, he discovered that he had been attending a basket weaving course by mistake, and with a sigh of relief he trotted down the corridor to join the electronics class.

He arrived just in time to hear the teacher say that op-amps should have very high gain — the higher the better — otherwise the formulae for feedback resistors and things would not be accurate. Then it was time to go home. His homework was to make an amplifier with a gain of exactly 1000.

Next day Alf went to the stationery cupboard, got a new pack of envelopes to write on the back of, and set about designing the best op-amp in the world. His Pterodactyl 'Guide To Op-amps' (Pterodactyls were precursors of Penguins) told him that op-amps normally had gains of about 10^5 to 10^6, so the first thing was to increase this as much as possible.

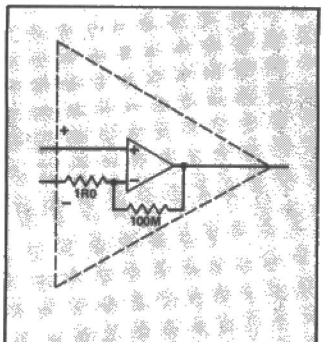


Fig. 1 Alf's Super-gain op-amp.

He took an op-amp out of his drawer, a handful of 10M resistors, and built up the circuit of Fig. 1. The 100M resistor was made from ten 10M resistors in series.

Alf worked out that his circuit should have a gain of 10^8 — about a hundred times as good as an ordinary op-amp. 'Who cares if it's not quite accurate?', he thought. 'I'll settle for a gain of more-or-less 10^8.'

He put the circuit in a plastic box, pured epoxy resin over it, and labelled it 'Alf's Super-gain Op-amp'. Then he took a pair of resistors and made the usual feedback arrangement to give a gain of 1000 (Fig. 2).

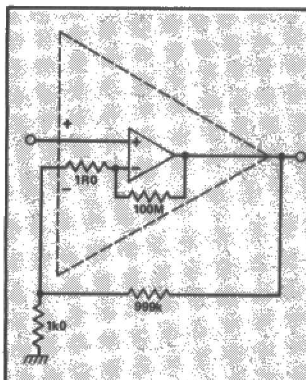


Fig. 2 Highly accurate gain setting?

The following week he couldn't wait to show off his circuit to the class, being sure that it would be 100 times as accurate as everybody elses. Do you think it was any better? If not, what is wrong with Alf's reasoning?

The answer to last month's puzzle:

The working circuits are a, d and e. The rest are duds.

OPEN CHANNEL

A proposed service for the integrated services digital telephone network (ISDN) is to transmit video images in digital form. Users of the ISDN can, theoretically, see as well as speak to each other at each end of the telephone line — a videophone, no less. But has anyone stopped and had a quick think about the sort of data rate this requires?

No Einstein

A data rate of well over 100 Megabits/sec is needed to transmit a fully fledged television picture. It doesn't take an Einstein to realise that this sort of transmission is totally out of the question.

There are fairly easy and well-accepted methods of reducing the quality and hence the required data rate to transmit the picture. Initially the scan rate (the speed at which the original scene is detected by the camera) can be reduced, resulting in transmissions of, say, 10 complete scenes per second instead of the 25 in existing television systems.

Secondly, it's possible to transmit only those parts of the scene which have changed since the last scene was transmitted — those parts which haven't changed aren't transmitted; the receiving system displays them exactly as they were in the previous scene. Finally, the number of resolvable picture elements, or pixels, can be greatly reduced; from about 570 (horizontally) by 400 (vertically) for a television system, to say, 352 by 288 for a videophone system.

Videophone systems using these techniques require in the region of 2 Megabits/sec of data rate capability, a reduction in data rate of over 50 times that of a familiar television picture transmission.

This might all sound great to potential users of the ISDN service, but remember that individual users of the ISDN will have access to the network via 65 Kilobits/sec nodes. It will take some 32 parallel nodes between two users of the ISDN to allow videophone transmision!

This is not usually possible (because of cost) to individual users. Business users, on the other hand, can have (and presumably afford) multi-line access nodes of 2 Megabits/sec capacity, specifically intended for PABX connection but usable for videophone services as required. Handy, huh?

The German-based electronics company, Siemens, have been researching possible ways of reducing the required data rate and seems to have its hands on a viable answer. Instead of transmitting strings of binary digits, each of which represents the intensity at each pixel of the scene (the usual method of digital picture transmission), the Siemens method first breaks up each scene into squares of 16-by-16 pixels and then transmits data which corresponds to the image content of each square. Only 396 data strings will thus have to be transmitted for every scene of a 352 by 288 pixel videophone system (a mere 22-by-18 sixteen-sided squares), as against the 101,376 data strings normally transmitted.

Even allowing for the fact that the square data strings will of necessity be much longer than the individual pixel data strings, the potential for reduction of required data rate is enormous if the system can be made to work.

In practice, Siemens has been messing around with discrete cosine transformations to provide data strings which adequately describe the image content of the squares, and this method appears to be OK. Siemens hope to be able to cut the required data down to, initially, 383 Kbits/sec and eventually 64 Kbits/sec — the data rate which a single access node of the ISDN provides. Videophones may yet be with us.

My Favourite Subject

Direct broadcast by satellite (DBS) will be in the news shortly, if not already by the time you read this, because the Independent Broadcasting Authority is scheduled to reveal the licensed franchisees who will provide the three channels to be transmitted, by the end of the year (1986, that is). On revealing this news the IBA will automatically define the content of the channels — that's quite a responsiblity, and not to be envied.

It's interesting to note that out of the five channels which the UK has been allocated for the services only three are to be used, with no plans (at the time of writing) for the remaining two. It may be that they will be leased to other prospective franchisees with the proviso that if one or two channels of the three *allocated* franchisees breaks down the remaining channels will be re-allocated leaving the leasing body without a channel.

It may be the extra channels will not be used at all. Or it may be the channels will be allocated to a large broadcasting corporation which just happens to have two terrestrial-based television channels which could quite happily be transmitted by satellite (mentioning no names, Auntie).

Whatever the situation, DBS will not provide the sort of channel variants which it was first thought may occur, nor will it provide the sort of television revolution which we all initially anticipated. Despite all the media hype about the Japanese and American high definition television system (HDTV), DBS in the UK will probably use the C-MAC (multiplexed analogue component, version C — if you must know) format, although it is just possible that version D2 of the MAC format (D2-MAC) will be adopted if anyone voices a serious demand for it.

Anyway, C-MAC or D-MAC, you can forget HDTV. Nonetheless, the UK DBS system will provide much higher definition than existing terrestrial-based television services, but only if new receivers are used. Existing receivers can be adapated to receive DBS transmission but definition will only be the same as existing terrestrial broadcasts — the definition is limited by the receiver.

So why aren't we seriously considering HDTV? Well, even if the bandwidth allocated to DBS channels was large enough to transmit HDTV format pictures, which it isn't, existing receivers could never be used to receive an HDTV transmission. And that would mean all potential users of the service would have to buy a new receiver — an enormously expensive receiver at that. Using MAC format, potential users have the choice of adapting the existing receiver or buying a new receiver which is itself merely an adapted version and therefore will not be quite so expensive as a pure HDTV receiver. So MAC format, of one form or another, it is.

Keith Brindley